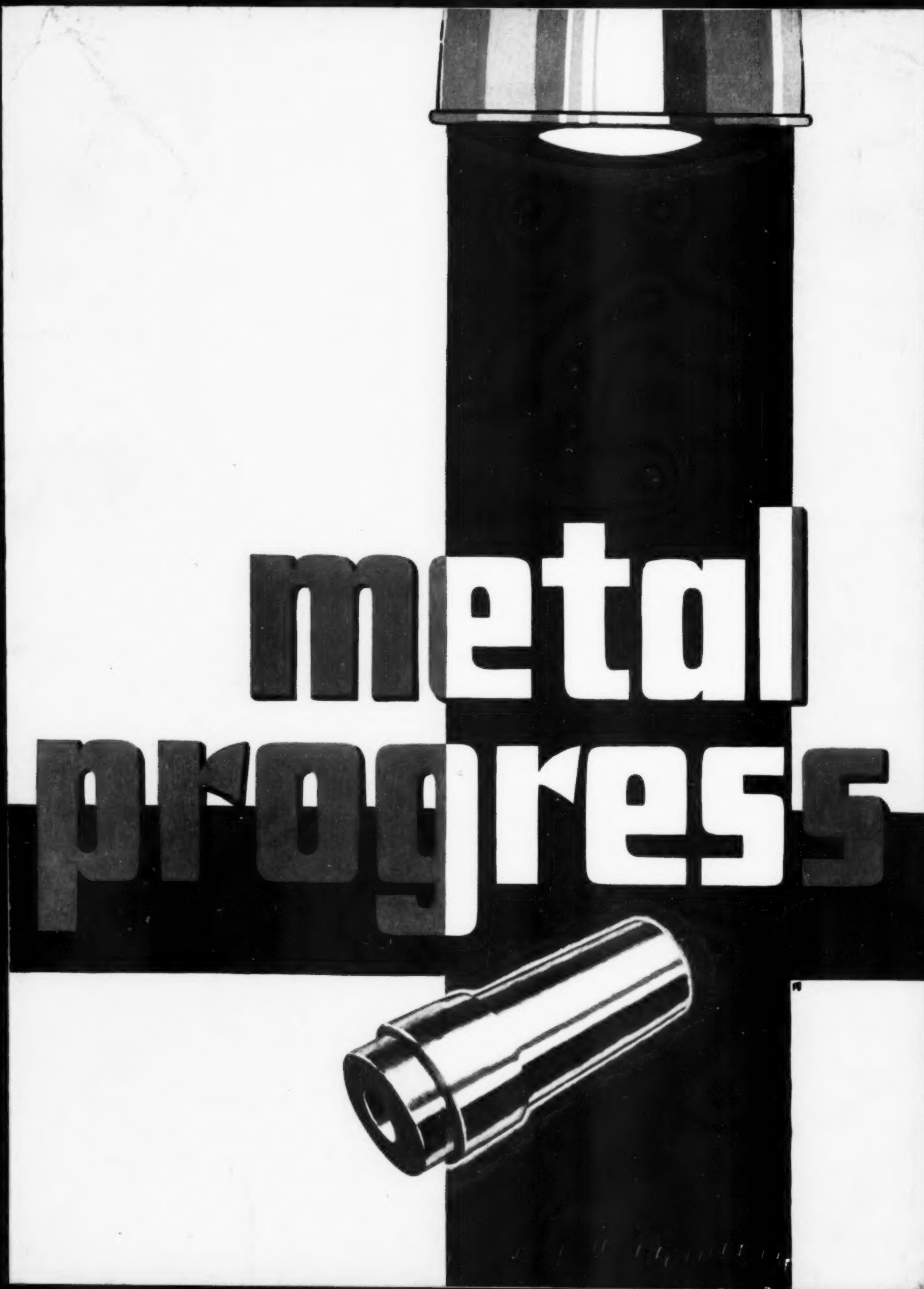
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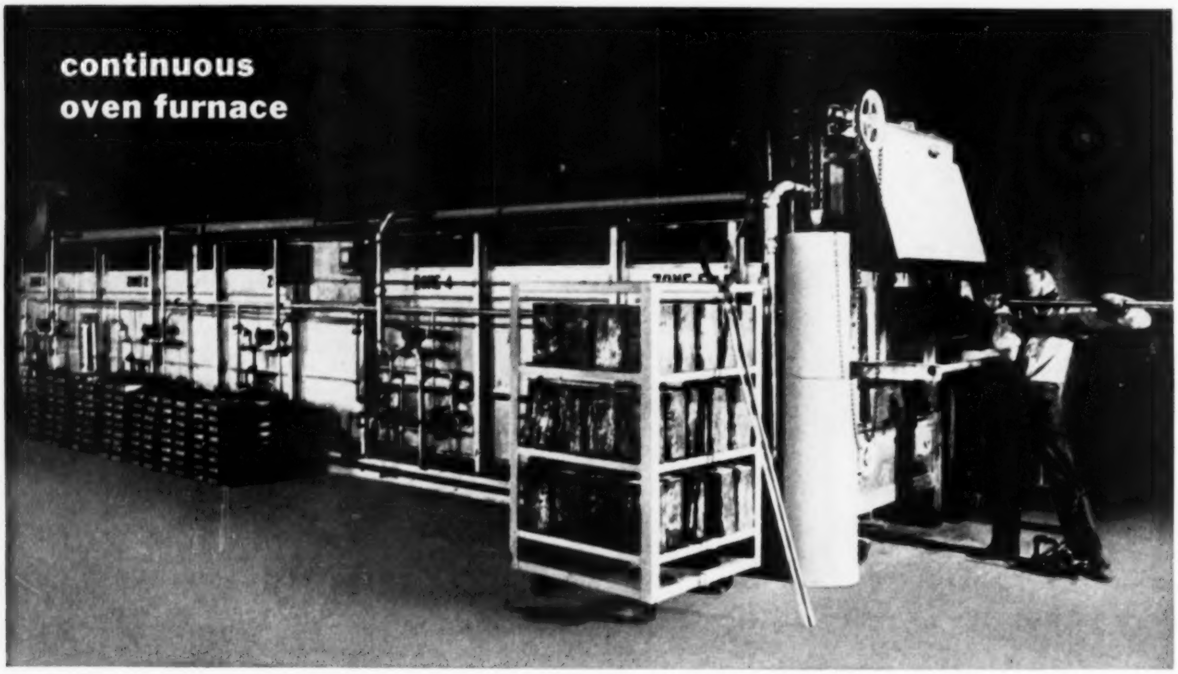
continuous
oven furnace

Metal Progress

September, 1954 **Vol. 66, No. 3**

Ernest E. Thum, *Editor*
Marjorie R. Hyslop, *Managing Editor*
John Parina, Jr., *Associate Editor*
Floyd E. Craig, *Art Director*

Cover by Don Arnstine
Black Light Inspection

Engineering Articles

Book Reviews

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Table of Contents Continued

As I was saying...

THE SUMMER MONTHS are the warmest and busiest of the year for the home office of the A.S.M. When all other ASMembers (so I'm told) are taking a vacation it's probably just as well for us to be busy. "Well, Bill, what keeps you busy?" I seem to be always hearing someone ask. So I'll hedge a little and let you in on a fact you may have already realized—it is that I don't do very much myself. I just delight in acting as a straw boss (you can knock me over with a feather) and I keep jotting down things the staff should do tomorrow and the next day and then see that the list of things to do is circulated to all concerned.

While this job of mine, sometimes called "ridin' herd", may sound like a heck of a Simon Legree activity, it's indeed a pleasant one, since I believe I have beyond all doubt the best congregation of dedicated ASMers ever assembled in the service of 24,000 members. I've been fortunate to gather around me a group of experts who know more about the subjects they have to deal with than I do and I am might happy that is so. It makes for accomplishments that give credit to the Society.

Would you believe it—we are now preparing floor plans and details for the Philadelphia Show in October '55, and have just confirmed dates for the Metal Show in '58 and expect to close on '59 dates sometime next month. Just this month we assigned spaces (94% sold) for the Western Metal Exposition in the Pan-Pacific in Los Angeles, March 28 to April 1, 1955. The Chicago Show, Nov. 1 through 5 of this year, with the seminar starting on Saturday and Sunday preceding, has been given its finishing touches. The technical papers will all be preprinted and distributed by Sept. 15. The Official Program and the convention issue of *Metal Progress* (October) have been planned and are now almost ready for bed. Many new features will be inaugurated for the Chicago Show. Watch the program and announcements carefully. With the Show another S.R.O., we have been able to devote all our time to planning: 1) to increase the interest in the program; 2) to bring more interested manufacturing personnel to the Show. Unless all signs go to the contrary, both these endeavors will be succcessfully accomplished.

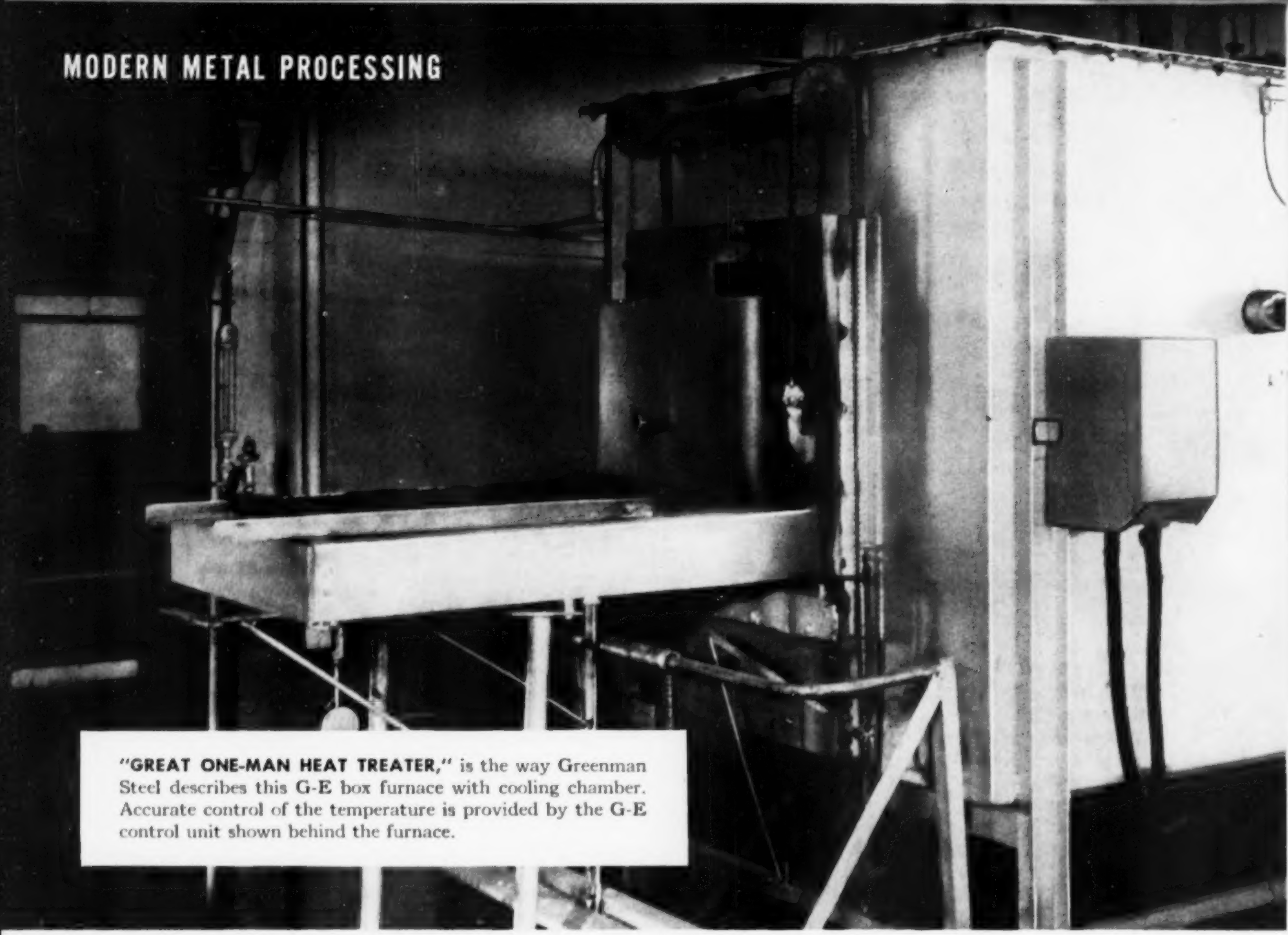
I have just returned from a jaunt through the East and had the pleasure of meeting with the chairmen and vice-chairmen of more than 35 chapters. At these meetings the agenda included the following: technical programs, meetings, education, membership, student affairs, public relations, Science Achievement Awards and others.

If anyone should ever ask you what is "the spark" that has made a leader in the field of engineering societies, you will be 100% correct if you answer, "The spark is supplied by and really is the wholehearted acceptance of their responsibilities by the members elected as the executive committees and officers of the chapter. They tackle the assignment with a spirit and determination for success that brooks no opposition and overcomes every road block. Their enthusiasm is contagious and the splendid leadership they display fires all the members to greater achievements. That's the Spark that lights the road to Progress and Success."

Cordially yours,

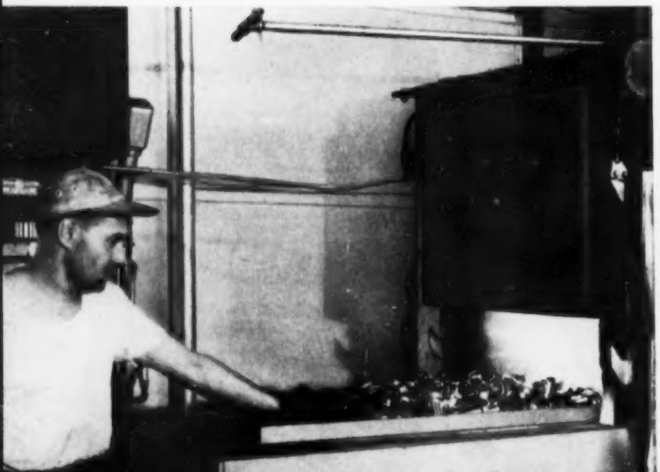
Bill

W. H. EISENMAN, *Secretary*
AMERICAN SOCIETY FOR METALS



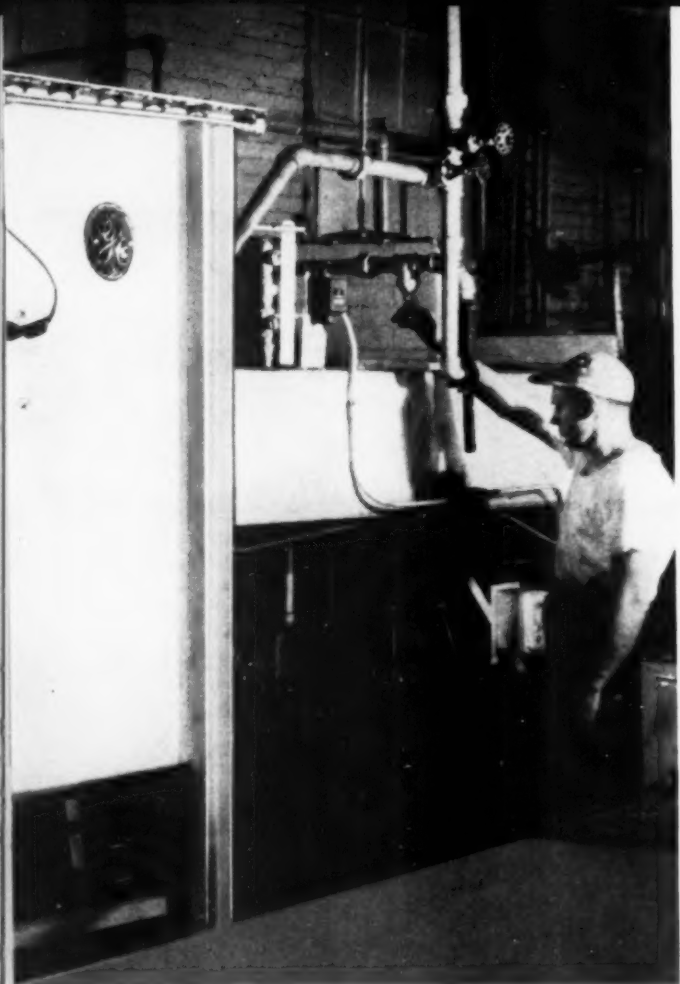
"GREAT ONE-MAN HEAT TREATER," is the way Greenman Steel describes this G-E box furnace with cooling chamber. Accurate control of the temperature is provided by the G-E control unit shown behind the furnace.

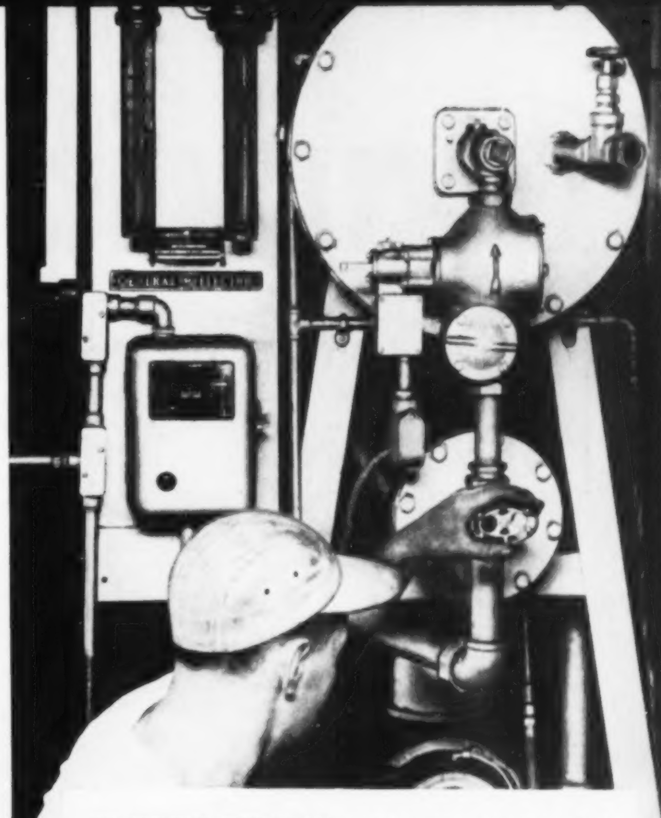
"Versatility of G-E Furnace Almost



MANY HEAT-TREATING JOBS can be done with this one G-E box furnace. Greenman Steel uses it for copper brazing, silver brazing, annealing, and hardening. Here, the furnace is employed to anneal drawn-steel cups.

HIGH-QUALITY WORK is achieved by moving the parts directly from the furnace to the atmosphere cooling chamber, thereby minimizing oxidation. Here, the parts emerge from the cooling chamber clean and bright.





TO PREVENT OXIDATION, metal parts are heat treated and cooled in a protective atmosphere produced by this G-E atmosphere gas converter.

Unlimited," Says Industrial Heat Treater

Operational savings of G-E furnace keep Greenman Steel competitive

Heat-treating jobbers who demand versatility in a furnace find that General Electric's box furnace with water-jacketed cooling chamber is ideal for general-purpose work.

Says Lloyd G. Field, General Manager of Greenman Steel Treating Corp., Worcester, Mass.:

"As a heat-treating jobber, we have to produce high-quality work at lower cost than equipment manufacturers can do it themselves. We must be ready to handle all sorts of heat-treating jobs, yet our investment in equipment must be kept to a minimum. We find that our G-E box furnace satisfies all these requirements. It enables us to stay competitive because it produces superior work at low cost. It minimizes our equipment costs because its versatility is practically unlimited. We use it to copper braze, silver braze, anneal, and harden."

MANY SAVINGS, HIGH-QUALITY WORK

Mr. Field pointed out that operating costs are low because the insulating qualities of the furnace minimize heat loss. Automatic control of the heat assures him of high-quality work.

FOR APPLICATION HELP

Whether your operation demands a small-capacity, all-purpose furnace, or one that is engineered for a particular process and intended for high-production rates at the lowest possible cost, General Electric can satisfy your requirements. For application help from a G-E Heating Specialist, contact your G-E Apparatus Sales Office.

GENERAL ELECTRIC

WRITE NOW FOR THESE MODERN METAL PROCESSING BULLETINS

- Furnace and Induction Brazing, GEA-5889
- Annealing Malleable Iron, GEA-5797
- Forging with Induction Heat, GEA-5983
- Heat-treating Aluminum, GEA-5912

Address: General Electric Co., Section 720-129, Schenectady 5, N. Y.

Marvibond

New vinyl-to-metal laminating process

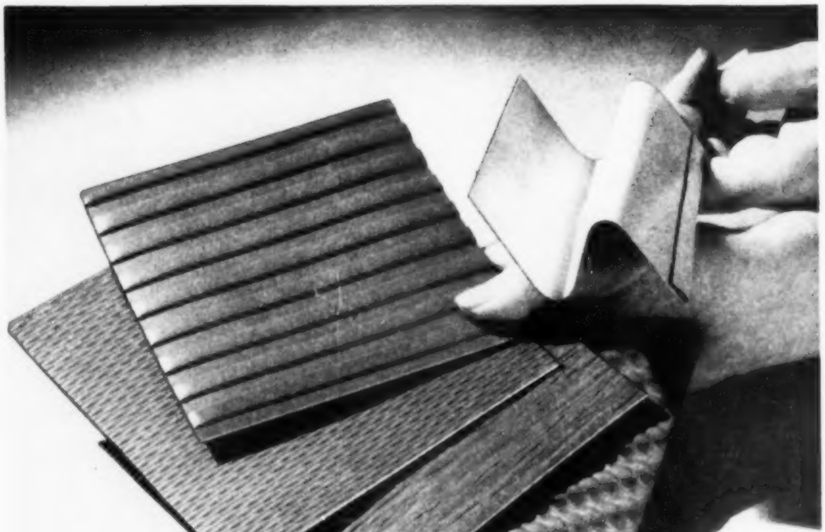
Naugatuck's new and exclusive laminating process bonds Marvinol® vinyl sheeting to practically any kind of sheet metal—permanently! It gives metals all the famed corrosion and chemical resistance of vinyl plastic, one of the most inert of all known materials!

New Marvibond laminates end rusting—resist acids, alkalies, salt water, alcohol, household chemicals, corrosive industrial liquids and atmospheres . . .

- **give far greater corrosion and abrasion resistance than galvanized steel—much superior to varnish, phenolic, or alkyd finishes!**
- **withstand weather and humidity indefinitely!**
- **remain dimensionally stable up to 250°F!**
- **take more than 40 lbs. per inch in lap-off tests!**
- **will not chip, crack, craze, or flake off!**
- **will not support combustion!**
- **can be deep drawn, sheared, crimped, bent, embossed, drilled, and punched—with standard tools—*without damage to coating or bond!***
- **and cost less than stainless steel!**

Since Marvibond involves lamination rather than spraying, it gives all the excellent chemical, abrasion, and heat resistance of a polyvinyl chloride—protection not obtainable with a solution grade vinyl. *And it gives this superior protection at less cost.*

Illustrated are just a few of the many forms and products into which Marvibond has been fashioned—suggesting the tremendous scope of product possibilities this new process opens up.

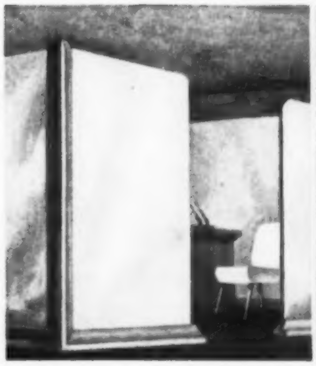


gives metal the corrosion resistance of vinyl plastic!

Why not Marvibond for...

shower stalls?

small toys, carts, and accessories?



decorative panels and office partitions?

furnishings for home, office, or hospital?

Why not these and hundreds more . . . chemical ducts and processing equipment . . . machine housings . . . containers of all sorts . . . electrical switch boxes and plates . . . metal tiles . . . table tops . . . air washing systems . . . countless products of practically every description.

Why not *your* product? If it's made of sheet metal (or could be), Marvibond offers both beauty and protection unexcelled. Better write to the address below for more details and sample test data.

50TH ANNIVERSARY 1904 1954 NAUGATUCK CHEMICAL

Naugatuck Chemical

Division of United States Rubber Company

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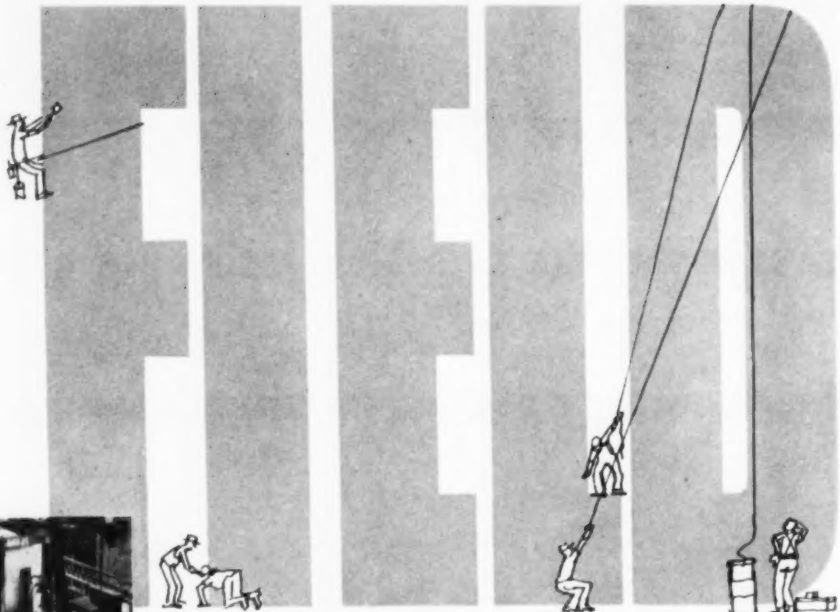
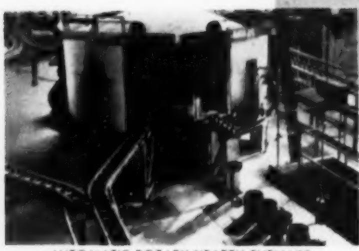
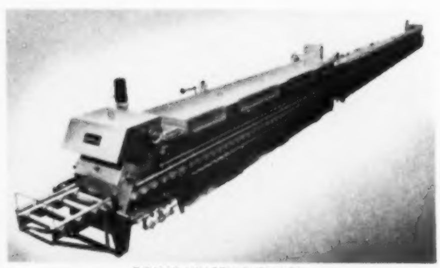


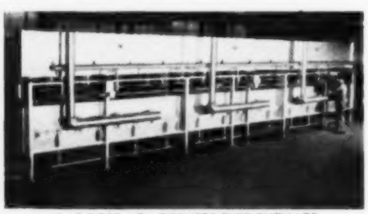


AUTOMATIC ROTARY HEARTH FURNACE

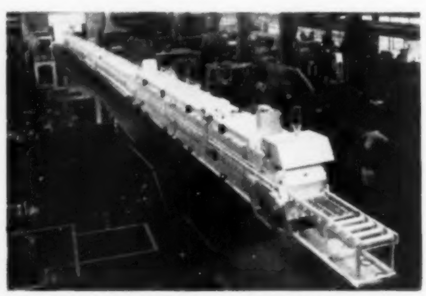


ROLLER HEARTH FURNACE

CONTINUOUS MESH BELT RECIRCULATING FURNACE

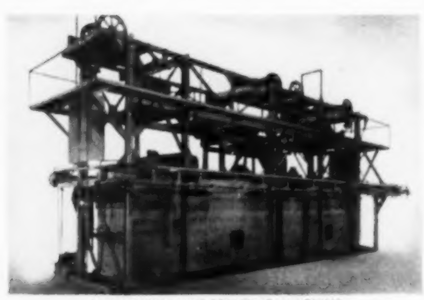


GAS-FIRED ATMOSPHERE TYPE FURNACE

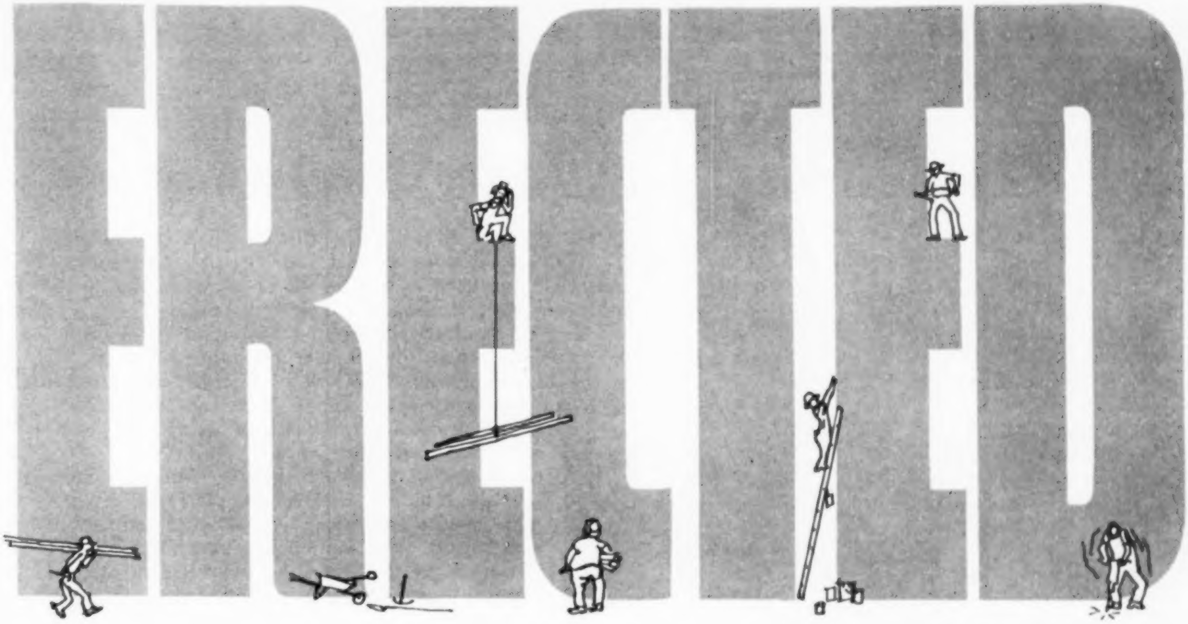


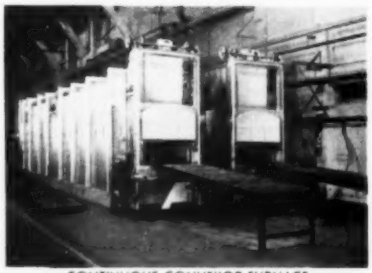
CONTINUOUS ELECTRIC FURNACE

ALUMINUM BILLET HEATER



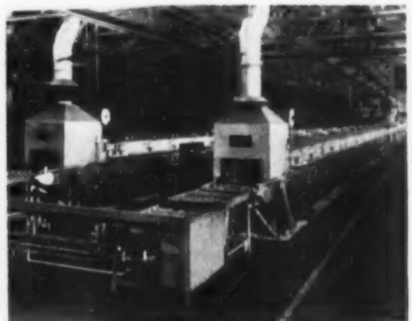
AUTOMATIC HEAT TREATING MACHINE





CONTINUOUS CONVEYOR FURNACE

AUTOMATIC ROLLER GRID FURNACE



CONTINUOUS BRAZING PRODUCTION LINES

CONTINUOUS VITREOUS ENAMELING LINE

CONTINUOUS CARBO-NITRIDING FURNACE

BIG ONES...by Lindberg

Maybe you haven't heard the news. Lindberg is now set up to field-erect any type of industrial heating or processing installation. Pictured on these pages are just a few of the large field-erected installations already put up by Lindberg. More are being built right now.

You get a complete package deal from Lindberg. Expert engineers consult with you and analyze your needs. Then they plan and design an installation to meet your specific requirements, whether you need a single furnace or a complete production line. And Lindberg will build it for you, right in your own plant.

To get on-the-spot service from an expert Lindberg engineer, just call your nearest Lindberg Field Office (you'll find the number in the classified section of your phone book, or in the Trade Directories).

LINDBERG INDUSTRIAL

LINDBERG INDUSTRIAL CORPORATION

Chicago Plant: 2321 West Hubbard Street, Chicago, Illinois

Field Offices in principal cities. **Los Angeles Plant:** 11937 Regentview Avenue, at Downey, California • **Associate Companies:** Lindberg Engineering Company, Chicago • EFCO-Lindberg, Ltd., Montreal • Lindberg Italiana, Milan, Italy

engineering digest OF NEW PRODUCTS

Semi-automatic Hardness Tester

A Rockwell motorized hardness tester, which is semi-automatic in operation, has been announced by the Wilson Mechanical Instrument Div. The device features a short test cycle to permit an increased number of Rockwell readings to be taken and recorded within a definite time period.

The motor's function in the test cycle is to remove the major load. The cycle of major load operation is less than 2 sec. Its application is controlled through a dash pot, which gives infinitely variable speed control. Power is supplied from a 110 volt, 60 cycle, single phase a-c line. The instrument features an illuminated dial gage, indenter light and the Set-O-Matic dial gage which returns the pointer to zero when minor load is applied.

For further information circle No. 950 on literature request card on p. 32-B.

Metal Cleaner

A new type of prephosphate metal cleaner to be used in mechanical spray processing equipment has been announced by the Detrex Corp. The cleaner is intended for use where a fine-grained phosphate crystal is required. It leaves the metal surface chemically clean and requires no surface seeding in the prephosphate coating stages. Subsequent phosphate coatings are extremely fine grained, uniformly coated and thereby result in lower chemical consumption. Activating is accomplished without resorting to metallic activators.

For further information circle No. 951 on literature request card on p. 32-B.

Rust Removal

A new rust removing material that simultaneously strips paint, rust and primer from ferrous metal surfaces has been announced by Turco Products, Inc. The liquid alkaline material requires only two simple steps—a hot tank dip and an air-and-water or steam pressure rinse. According to the manufacturer, it will remove slightly pitted rust in less than a minute, while heavy rust and multiple coatings of paint normally require an immersion of a few minutes. It contains no cyanide compounds, requires no electrolytic action and gives off no corrosive fumes.

For further information circle No. 952 on literature request card on p. 32-B.

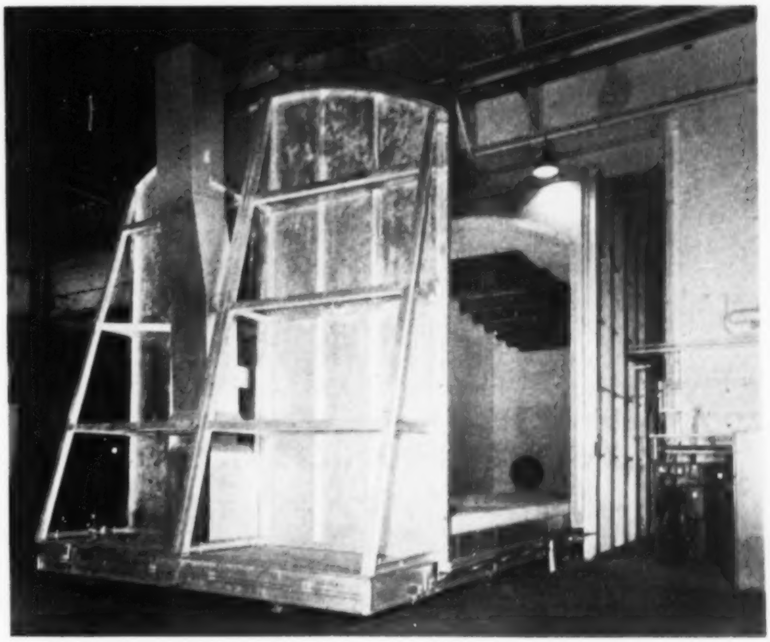
Titanium Carbide Cutters

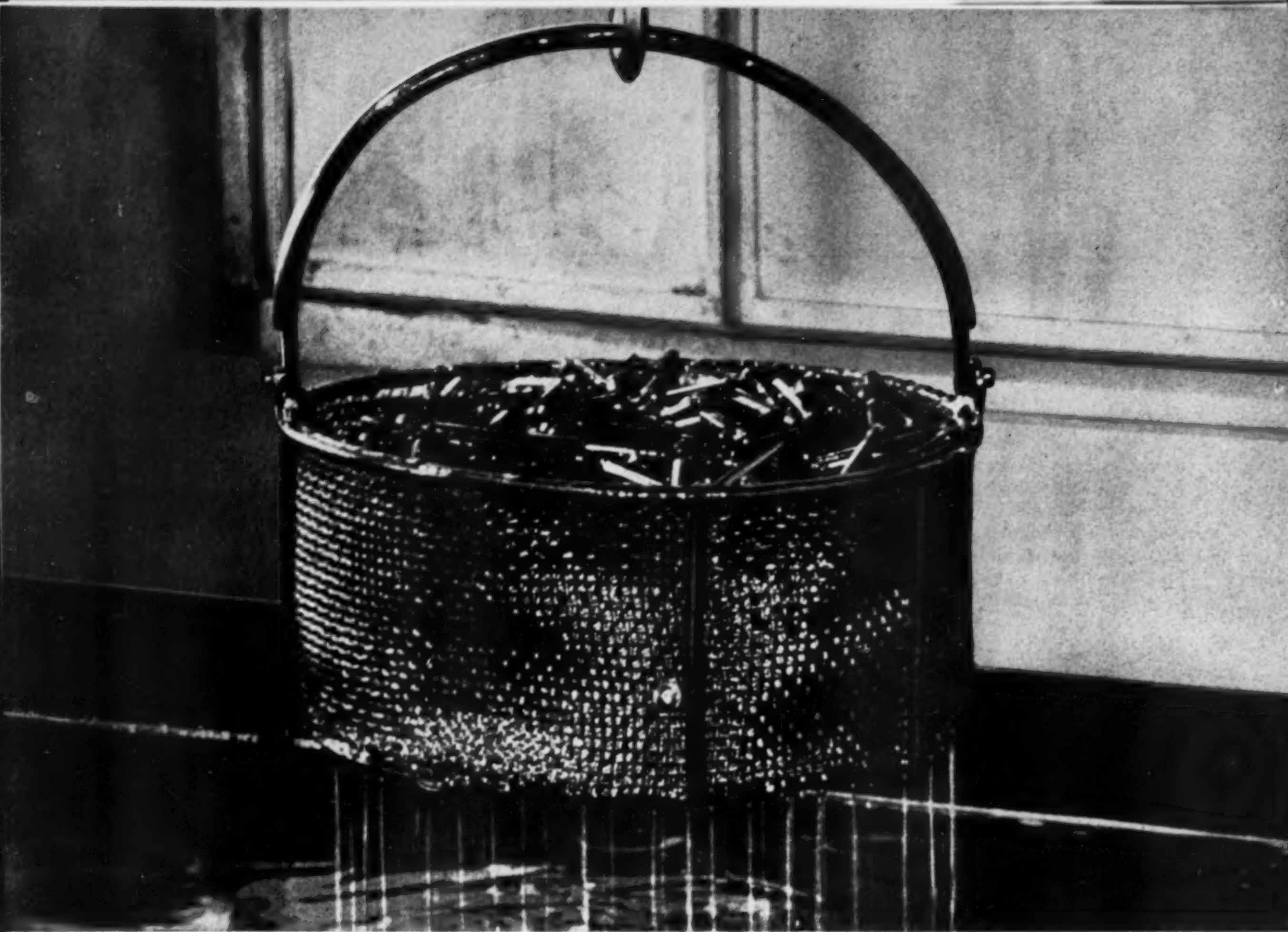
Firth Sterling, Inc., has announced the development of a new titanium carbide cutting material which contains no tungsten and no cobalt.

Large Single Chamber Heat Treating Furnace

A car-type heat treating furnace 30 ft. long, 18 ft. wide and 16 ft. high has been installed at the East Pittsburgh works of Westinghouse Electric Corp., and will be used for the stress relieving of large weldments. Parts weighing up to 100 tons may be treated at one time. Maximum operating temperature is 1600° F., but stress relieving will be performed at approximately 1175° F. The air passing through the combustion chamber is heated by the burning gas and enters the furnace from the rear through ducts suspended from the ceiling. This duct work distributes the heated air through various side openings as it travels toward the front. Air is drawn out of the furnace through two recirculating blowers having a total circulating rate of 120,000 cu. ft. per min.

For further information circle No. 953 on literature request card on p. 32-B.



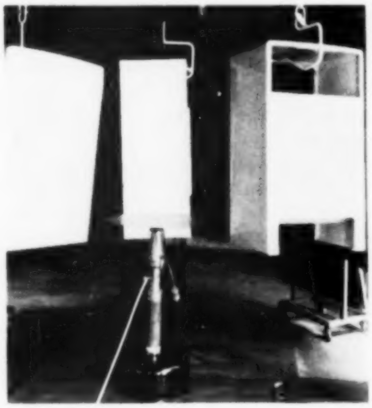


Nickel is used as a binder instead of cobalt, and molybdenum carbide is used as an alloy carbide addition. The tungsten-free grades are characterized by high wear resistance and the cratering action of steel chips is greatly reduced. Tool life is excellent on steady finishing cuts, particularly when high speeds and fine feeds are employed in machining hard abrasive steels. They remain cooler than tungsten carbide grades when cutting steel without fluids.

For further information circle No. 954 on literature request card on p. 32-B.

Paint Atomizer

A reciprocating, disk-type atomizer, used in electrostatic spray painting, has been announced by Ransburg Electro-Coating Corp. With the up and down motion, the unit provides uniformity in painting small parts and big products such as refrigerator cabinets and doors. Parts are hung on



a conveyor which makes a circular loop in the electrostatic spray area. The atomizer is located in a pit in the floor in the center of the loop. Paint is pumped to the center of the disk which rotates to feed paint to the atomizing edge. High d-c. voltage is imposed on the disk, establishing an electrostatic field between the disk and the parts hanging on the grounded conveyor. This atomizes the paint into a fine spray and electrostatically attracts it to the surrounding parts.

For further information circle No. 955 on literature request card on p. 32-B.

Plating Barrels

Cluster barrels, manufactured by the Udylite Corp., are being used in the production plating of millions of small parts for office machines. They provide a rotary rack to hold small containers with the proper constant current conducted to each container. The mechanism consists of a shaft rotated by means of a large ring gear. For loading and unloading, the small

containers are snapped out of the clips which hold them and the lids lifted off. Each container has a built-in disk-type cathode contact making it a complete unit in itself. The cluster barrel can be used in the standard plating

barrel. It is particularly well adapted to plating products where the parts must be kept separate or for plating small delicate parts which cannot stand the tumbling action of standard bulk plating equipment.

For further information circle No. 956 on literature request card on p. 32-B.

Gamma-Ray Inspection

A new gamma ray machine, using radio-active isotopes to peer into dense materials, has been announced by Gamma Industries, Inc. This machine can penetrate steel plate up to 8 in. thick and is completely portable. In operation, radioactive rays pass

through a dense article and strike against a photographic film in holders behind the test object. The film, when developed, reveals a shadow picture of the specimen and its internal structure. The machine does not require huge amounts of lead insulation. It comes with five Curies of Cobalt-60.

For further information circle No. 957 on literature request card on p. 32-B.

Thickness Measurement

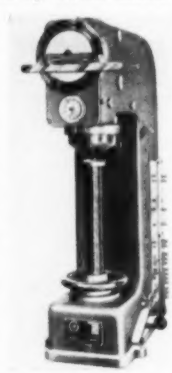
Nuclear Research Corp. announces a small angle radiation detection and presentation device for precise control functions, such as measuring minute variations in thickness throughout pieces of sheet steel or determining flaws in welds. The unit has three major components—a radia-

tion source, a counter which detects the beam after it has passed through the object being tested, and an electronic presentation system for noting and recording the variations in the beam. Further inspection applications are anticipated.

For further information circle No. 958 on literature request card on p. 32-B.

Hardness Testing

Reflex machines for Vickers, Knoop, Grodzinski, Brinell and Rockwell tests have been announced by Gries Industries, Inc. They feature test load capacities from 1 to 250 kg., push-button load selection and automatic projection. After the applied test load has been removed, the greatly magnified image (up to 140X) of the indentation produced is automatically projected on the ground glass screen.



The ground glass can be replaced by a photographic plateholder. Test values are based upon the area of indentation rather than upon the depth of indentation.

For further information circle No. 959 on literature request card on p. 32-B.

Ultrasonic Gage

A 21-in. television tube is a feature of the new automatic ultrasonic thickness gage announced by Branson Instruments. The instrument measures thickness and detects laminar

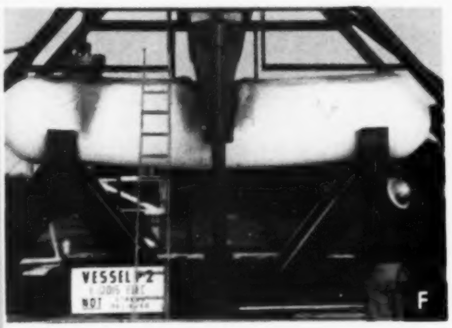
USS CARILLOY T-1 STEEL

DOWN TO 38°F. BELOW ZERO

E 12015 low hydrogen coated electrodes. The other four were welded with E 9015 electrodes and were stress relieved after welding. Two vessels of each type were given two tests: a pressure burst test for strength and ductility, and an impact punishment test for toughness and resistance to the most severe impact conditions that could be devised.

Results of these tests, described below, prove conclusively the exceptional strength and toughness of USS Carilloy T-1 steel, even at temperatures far below freezing.

E



F


G

H

Frozen steel vessel made of Carilloy T-1 survives blow from 13-ton ingot dropped 73 ft.

A steel ingot weighing 26,700 lbs. has just plummeted 52 feet and crunched on top of this test vessel (Fig. E). The ingot was traveling 39 miles per hour when it hit. It struck with an impact energy of about 1,400,000 ft. lbs., bounced fifteen feet, and crushed down again on top of the vessel.

This vessel was welded without stress relieving. It was refrigerated to 33°F. below zero. It was pressurized to 1,875 psi. equal to a stress on the plates of 90,000 psi.—the steel's *nominal* yield strength. Yet, it did not fail. The ingot left only a 7/16 inch dent in the top, with a slight bulge on either side of the dent.

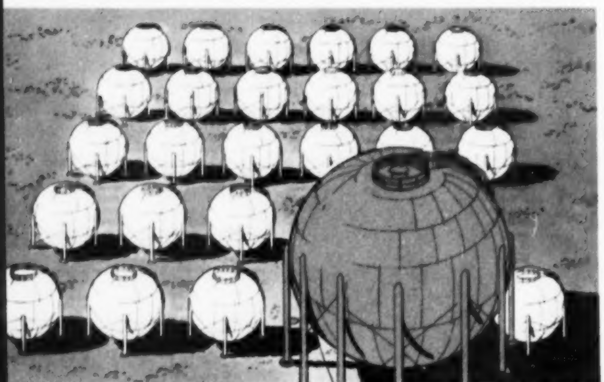
The test was repeated (Fig. F). This time the ingot was raised 73 feet, then dropped. It pounded down again on the very same spot on top of the vessel. Traveling at 46.7 miles per hour, it hit with an impact blow of 1,960,000 ft. lbs. The dent merely deepened—the steel and all welds were still intact.

Again the test was repeated (Fig. G). Now dropped from 101 feet, the 13-ton ingot ploughed into the top of the vessel at a speed of 55 miles per hour, hit with an impact of 2,750,000 ft. lbs. This time the vessel failed. But it didn't shatter. It didn't crack. It tore open like a tough piece of hickory. In other words, it failed without any signs of brittleness, even though the temperature of the steel was now minus 22°F.

In addition to this tremendous resistance to impact abuse, combined with remarkable sub-zero toughness, Carilloy T-1 steel also gives you excellent resistance to impact abrasion . . . good high temperature strength . . . and exceptional weldability.

Turn the page to see how you can use this remarkable new steel to cut costs and improve performance in a great variety of products.

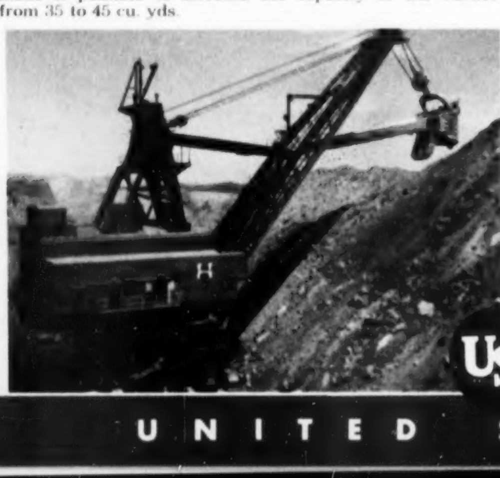
Here's where you can reduce costs with USS Carilloy T-1 steel



IN PRESSURE VESSELS. To illustrate how the high yield strength of Carilloy T-1 steel can pay off here, consider this fact: To store 25,000 bbls. of propane at 210 psi would ordinarily require 25 mild carbon steel vessels. In contrast, only *one* large vessel made of T-1 steel of the *same* thickness would do the job. This single T-1 vessel would require 1/3 less shell material, 14% less foundation concrete, 70% less welding and 84% less space.

IN STEEL MILLS. In skip cars, T-1 steel in the bottoms, sides, and bail plates lasts three times longer than steels now in use. T-1 steel also gives exceptionally long service in coke bins and chutes, in ore transfer cars, in draft lines, in conveyor chains, and crane hooks. In clamshell buckets, T-1 steel has taken heavy abuse at temperatures from 500° to 600° F. and lasted *nine times* as long as the wear resisting steel previously used.

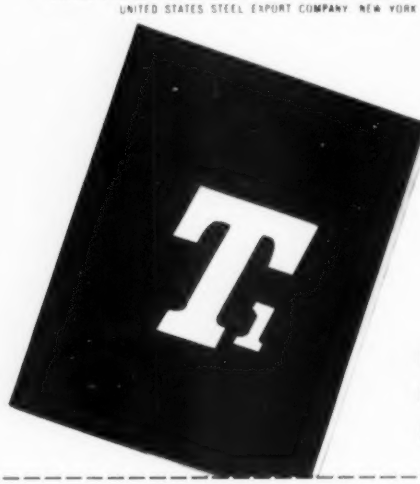
IN EXCAVATING EQUIPMENT. The dipper stick, bail, and bucket of this big electric shovel are fabricated of T-1 steel plate. The superior strength and durability of Carilloy T-1 made it possible to increase the capacity of the bucket from 35 to 45 cu. yds.



• The pressure vessel tests described on the previous pages indicate only one of the many possible uses of Carilloy T-1 steel. For this new engineering material has advantages not only in pressure vessels and storage tanks, but it also has proved itself in power shovels, bulldozers, mining machines, mine cars, steel mill ladles, blast furnace draft lines, lift trucks—in high speed rotating machinery, in stamping or forging presses. It is being considered for use in tension members of cantilever bridges and other similar applications where tension members are involved.

With the 90,000 psi. minimum yield strength to work with, combined with extraordinary sub-zero toughness, good high temperature strength to 900 F., and excellent resistance to impact abuse, impact abrasion, and atmospheric corrosion, you can use T-1 steel to reduce the size and weight of heavily stressed parts. This cuts your shipping and handling costs, as well as the cost of material, and the cost of foundations and supports where they are needed. Carilloy T-1 steel lengthens the life of your equipment, cuts repair bills and outage time. And remember, wherever you use T-1, you can weld or flame cut it either in the shop or in the field without expensive heat treating equipment. This cuts costs still further.

UNITED STATES STEEL CORPORATION, PITTSBURGH
COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO
TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA.
UNITED STATES STEEL SUPPLY DIVISION, WAREHOUSE DISTRIBUTORS
UNITED STATES STEEL EXPORT COMPANY, NEW YORK



SEND COUPON FOR COMPLETE INFORMATION.

United States Steel, Room 4481
525 William Penn Place
Pittsburgh 30, Pa.

☐ Please send me your booklet "United States Steel presents T-1" which contains the full story of T-1 steel.

☐ Have your representative get in touch with me.

Name ....

Address ....

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USS

UNITED STATES STEEL

flaws, including lack of bond nondestructively from one side of the work. A sweep-width adjustment permits wide choice of thickness scales, making it possible to read directly thicknesses from 0.012 to 2.5 in. with accuracies as high as 0.1%. Beyond 2.5 in., thicknesses up to 10 in. can

be calculated. The vacuum tube oscillator uses a specially designed variable inductor for the frequency sweep to vary the inductance instead of the capacitance. This has permitted replacement of a heavy, motor-driven capacitor with a small, self-contained, plug-in assembly without moving parts.

For further information circle No. 960 on literature request card on p. 32-B.

Measuring Magnetic Properties

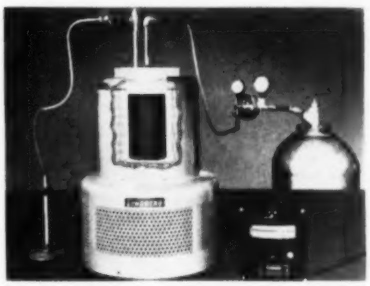
General Electric Co. has announced a new device for measurement and calculation of the magnetic characteristics of metal. The d-c. recording hysteresigraph traces the magnetic "signature" of a metal directly onto a scaled chart in a matter of minutes. It is able to compile and calculate these data with the use of two flux-

meters which integrate the flux voltage continuously. There are nine different sensitivities in the hysteresigraph ranging from a full scale reading of 0 to 2000 interlinkages to 0 to 1,000,000 interlinkages. These permit the accurate measurement of materials ranging from ferrites to high permeability nickel iron alloys. Its repetitive accuracy is better than 0.5%. It can draw the hysteresis loops of tiny ring specimens or of solid bar material.

For further information circle No. 961 on literature request card on p. 32-B.

Laboratory Dissociator

Lindberg Engineering Co. has announced the first commercial laboratory-size dissociated ammonia generator. A stainless steel catalyst chamber with a vertical inlet and outlet tube was designed to fit into the laboratory pot crucible furnace.



The tubes are welded to the cover plate of the furnace to form a complete gas tight unit. Pure nickel shot surround the tubes within the catalyst chamber. The furnace is brought to an operating temperature of 1900 °F. and held there. The ammonia cylinder is then cracked open, the raw ammonia gas flowed through and cracked in the catalyst chamber. A needle valve controls the flow of dissociated gas to the work. This flow is checked by a flow-meter and the gas then directed to the point of use.

For further information circle No. 962 on literature request card on p. 32-B.

Dry Abrasive Cutting Machine

The Campbell Machine Div. has announced a new dry abrasive cutting machine. This 62-in. high machine is available in stationary and portable types and has ample capacity for cutting solid steel bars up to 4 by 4 in., angles and channels up to 8 in., and tubes and pipes up to 4 in. outside diameter. Hand-operated self-centering workholders clamp the work on both sides of the cut or a foot-actuated treadle can be furnished.

Can <u>You</u> Use The "Grain That Stops Lightning"?

Crystolon* silicon carbide (SiC), electrochemically produced from silica sand and coke, is produced by Norton in many forms. One of these forms, E-179 crystolon grain, is known as "lightning arrestor grain" because of its carefully controlled electrical properties — obtained by specially controlled furnacing techniques, which lower its surge impedance.

In Commercial Lightning Arrestors

E-179 crystolon grain has the particularly useful property of acting as an insulator at low voltages and as a conductor at high voltages. This "valving" action, analogous to pressure-controlled valves in a fluid system, is provided in the arrestor circuit by a spark gap in series with an E-179 grain unit, loose or molded into blocks. The number of series used varies according to the arrestor's voltage rating.

The non-linear behavior of E-179 crystolon grain may be expressed in terms of voltage and current by the equation:

$$V = AI^n$$

where A is a constant for a given sample, and n, the exponent, is approximately 0.1 for E-179. For a material where the exponent n = 1, the equation becomes Ohm's Law: V = IR. The value of A is controlled by the method of manufacture. The exponent is constant over a wide range of surge impedance.

Ceramic Non-Ohmic Resistors

in the form of block, disc or rod are composed of a fired mixture consisting principally of a ceramic bond and E-179 crystolon grain. The nature of this crystalline silicon carbide determines the finished characteristics of the resistors. Both the nominal grain size and actual distribution of grain size around the nominal are factors which must be controlled.

E-179 crystolon grain is available in grit sizes from 60 to 240, inclusive, manufactured to customers' specifications, with impedance values measured for every lot of grain in each grain size.

Besides the applications mentioned, other uses for this special crystolon grain are: spark plug resistors, railroad blocks and discs, voltage control devices and varistors for telephones.

Regular CRYSTOLON Grains

share the common characteristics of great mechanical strength and resistance to heat shock. And in refractory applications the high thermal conductivity of crystolon material — 8 to 10 times that of ordinary fireclay — is a distinct advantage.

crystolon silicon carbide dissociates without melting at the extreme temperature of 4170°F. It is an acid refractory and at elevated temperatures resists all slags except those high in alkalies. Other characteristics include: maximum operating temperature — 2800°F; specific gravity — 3.20; bulk density — 98 lbs. per cu. ft.; hardness (Knoop) — 2500; crystal structure — hexagonal system, hemahedral class. A typical chemical analysis shows:

SiC	98.13%
Free SiO_2	.50
Fe	.25
Al	.25
Free C	.20
CaO	.15
Si	.50
MgO	.02

Regular crystolon material is used for: metallurgical additions; as a source of silicon for silicon tetrachloride base silicones; for electrical heating elements; and for refractory cements and shapes for industrial furnaces which utilize its high thermal conductivity, high hot strength and good thermal shock resistance.

Other Norton Basic Materials

include alundum* fused alumina, magnorite* fused magnesium oxide, norbide* boron carbide, Fused Stabilized Zirconia and many others, including a number still undergoing research and development.

These high-melting materials which have varied applications in many fields, are also the basic ingredients of the famous Norton Refractory R's — refractories *engineered and prescribed* for the widest range of uses.

For Your Own Applications or Developments

Norton Company not only supplies these materials in their crude form, but has extensive facilities for processing and fabricating — and is ready to work with you in engineering materials to your particular requirements. A new booklet "Norton Refractory Grain — Electrochemically Refined" contains detailed information on these interesting materials. Norton Company, 328 New Bond Street, Worcester 6, Massachusetts.

E-179 CRYSTOLON grain, which insulates at low voltages, becomes a conductor at high voltages, thus providing "safety-valve" action in this lightning arrestor. Processed by Norton to develop unique electrical properties, this high-purity silicon carbide grain is finding an ever-widening field of usefulness.

NORTON
REFRACTORIES

Engineered... R... Prescribed

Making better products... to make other products better

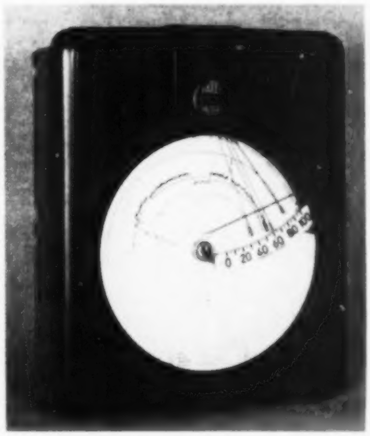
*Trade-Marks Reg. U. S. Pat. Off. and Foreign Countries

The cutting time is approximately 3 sec. per sq. in. of material cut. The cutting wheel is totally enclosed except for work clearance openings on the sides of the guard.

For further information circle No. 963 on literature request card on p. 32-B.

Recorder

The Bailey Meter Co. has announced a receiver recorder for pneumatic and electric transmission systems in power and process plants. Plug-in, precalibrated receivers provide continuous, independent records of one to



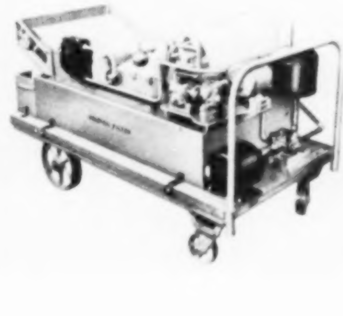
four pneumatic and electric transmissions in any combination. Receiver units may be added or interchanged, permitting easy field adaptation to new or revised metering and control applications.

For further information circle No. 964 on literature request card on p. 32-B.

Portable Filtration Unit

A new portable filtration unit incorporating the disposable belt-type filter has been announced by the Industrial Filtration Co. Units are mounted on casters for transportation for periodic filtration of various liquids and oils which do not require continuous filtration. They make use of a variety of filter media for numerous filtration requirements.

For further information circle No. 965 on literature request card on p. 32-B.



FROM SINCLAIR RESEARCH COMES . . .

A New Concept In Quenching Oil

the SINCLAIR QUENCHOL 500 SERIES

Sinclair introduces a premium product *which assures performance results heretofore unobtainable in conventional quenching operations.* Research has shown how quenching oils can be fortified with high cooling power characteristics. The high sludge resistance and low acid formation properties of QUENCHOL® is further evidence of its superiority – due in part to the high quality, high viscosity index Phetone Processed base oil selected for its formulation.

Important Advantages of Quenchol

- Reduces rejects
- Increases quality production at reduced cost
- Provides minimum drag-off and oil loss due to vaporization
- Improves quality control
- Provides greater flexibility in quenching various grade steels
- Offers an opportunity to upgrade lower cost steels for more critical usage

If you would like to see QUENCHOL in action, consult your local Sinclair representative for further details and a demonstration, or write for a free copy of "Quenching Oil" – a 12-page book on the new Sinclair QUENCHOL 500 Series. Gives results on hot wire quench test and in plant operation. *No obligation.* Sinclair Refining Company, 600 Fifth Avenue, New York 20, N. Y

SINCLAIR

WHAT'S NEW IN MANUFACTURERS' LITERATURE

987. Abrasive Wheels
Operating suggestions and recommended wheels for finishing stainless. *Manhattan Rubber Div.*

988. Alloy Castings
22-page bulletin 2041 on heat and corrosion resistant castings. *Blaw-Knox*

989. Alloy Steel
16-page book on type 9115 low-alloy high-strength steel. Properties, fabrication, welding. *Great Lakes Steel*

990. Alloy Steel
Leaflet on "Jalloy, Grade 3" special alloy steel for heavy duty use. Heat treatment, applications, properties and composition. *Jones & Laughlin Steel*

991. Alloy Steel
Data book on the selection of the proper alloy steel grades for each manufacturer's needs. *Wheelock, Lovejoy*

992. Aluminum Alloy
8-page bulletin on Ternalloys, high-strength aluminum base alloys, gives composition, properties, castability, machinability, welding and brazing. *Apex Smelting Co.*

993. Aluminum Cleaning
48-page booklet gives practical tips on materials and methods of cleaning aluminum and magnesium. *Oakite*

994. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

995. Aluminum Forgings
Booklet describes facilities for aluminum extrusion and forging. *Bridgeport Brass*

996. Ammonia Dissociators
Bulletin on dissociating process gives advantages of ammonia as controlled atmosphere. *Sargeant & Wilbur*

997. Atmosphere Furnace
Bulletin on controlled atmosphere furnace. *Industrial Heating Equipment*

998. Atmosphere Furnace
Information on mechanized batch-type atmosphere furnaces for gas cyaniding, gas carburizing, clean hardening or carbon restoration. *Dow Furnace*

999. Atmospheres
8-page Bulletin SC-155 discusses following controlled atmospheres: RX, DX, NX, HNX, AX, HX. Compositions, applications, effects on steel, drawings of generators. *Surface Combustion*

1000. Atmospheres
Bulletin 439 on exothermic atmosphere generators for converting natural gas, manufactured gas, propane or butane. *W. S. Rockwell*

1001. Barrel Finishing
New brochure on tumbling barrel and the deburring and burnishing of stampings, castings and other metal parts. *Abbott Ball Co.*

1002. Basic Materials
24-page booklet on Alundum, Crystolon, Magnorite, Norbide, zirconia, carbides, borides and other basic materials. Products made from them are listed. *Norton*

1003. Bending and Cutting
Folder describes hand and air-operated bender-cutter and its applications. *J. A. Richards*

1004. Beryllium Additive
4-page leaflet on aluminum and magnesium-base master alloys for making beryllium additions to light metals. *Beryllium Corp.*

1005. Beryllium Copper
New 4-page bulletin on beryllium copper strip. Sizes of strip, engineering properties, tempers. *American Silver Co.*

1006. Black Oxide Coatings
8-page booklet on black oxide coatings for steel, stainless steel and copper alloys. *Du-Lite*

1007. Black Oxide Finish
Folder on penetrating black finish for ferrous metal. *Puritan Mfg.*

1008. Blackening Stainless
Bulletin on process for blackening stainless steels, cast and malleable irons. *Mitchell-Bradford*

1009. Boron Additive
6-page article on use of grainal as boron-additive alloy and properties of grainal steels. *Vanadium Corp.*

1010. Brass
Bulletin B-39 on Formbrite drawing and forming brass. *American Brass*

1011. Brass
80-page book on properties and uses of brass forgings, sand castings, rods and machinings. *Mueller Brass*

1012. Brazed Tubing
12-page data book on brazed tubing made from copper coated steel. *Bundy*

1013. Brazing
Discussion of brazing of SAE-1010 bicycle forks in a mechanized salt bath furnace. *Ajax Electric*

1014. Brazing Aluminum
12-page bulletin, ADR 45, on how to torch braze aluminum and strength of joints so brazed. *Air Reduction Sales*

1015. Brazing Titanium
Data sheet on use of a new flux for brazing titanium. *Handy & Harman*

1016. Brinell Machine
Data on semi-automatic Brinell testing machine. *Detroit Testing Machine*

1017. Burners
Bulletin on piloted entrainment burners gives information on construction and specifications. *Eclipse Fuel Engineering*

1018. Burners
16-page bulletin on selection of gas burners. *Western Products*

1019. Cam
Bulletin on three dimensional cam which has 720 stations on just 1 sq. in. of surface. Engineering and production data. *Parker Stamp Works*

1020. Carbon and Graphite
20-page catalog on carbon and graphite applications in metallurgical, electrical, chemical, process fields. *National Carbon*

1021. Carbonitriding
28-page booklet on nature of process, furnaces, atmospheres, parts carbonitrided and properties. *Armour Ammonia*

1022. Carbonitriding
Bulletin 241 on gas-fired radiant-tube furnace for carbonitriding and other heat treating. *Lindberg Engineering*

1023. Case Hardening
Bulletin 159 describes standard rated batch furnaces for case hardening. *Surface Combustion*

1024. Centrifugal Castings
Booklet on spun centrifugal castings of bronze for liners, rings, rolls, sleeves, bushings. *American Non-Gran Bronze*

1025. Ceramic Coatings
8-page bulletin on ceramic coatings for high temperatures. Their advantages on steel and aluminum. *California Metal Enameling Co.*

1026. Chromate Coatings
Folder gives characteristics and uses of chromate conversion coatings on nonferrous metals. *Allied Research*

986 Corrosion Resistant Casting Alloys

Thirteen data sheets on corrosion resistant castings present information for the user on the commercially available alloys. Each sheet gives a description of the alloy dealt with, its heat treatment, applications, summary of properties, design and

fabrication considerations and designations for the alloy. The compilation has been made by the Specifications and Designations Committee of the Alloy Casting Institute. Data have been collected from many sources and in cooperation with such groups as the A.S.T.M. and the S.A.E. *Alloy Casting Institute.*

1027. Chromium Cast Iron
48-page book on effects of chromium on properties of cast iron. Data on production and uses. *Electro Metallurgical*

1028. Clad Metals
24-page booklet on principles of bonding, characteristics of clad metals, methods of cladding and applications. *Superior Steel*

1029. Clad Wire
Booklet on properties of nickel-clad copper wire for conductivity use at high temperature. *Sylvania Electric*

1030. Cleaner
Folder gives data on metal cleaners for

use with water in still-tank or spray-washing equipment. *Solventol*

1031. Cleaners
Bulletin on alkaline metal cleaners and solvent degreasers. *Park Chemical*

1032. Cleaning
Data sheets on acid activators to promote removal of scale and oxides from steel and iron. *Swift Ind. Chem.*

1033. Cleaning
8-page bulletin on cold solvent type metal cleaning machines and parts washers. *Graymills Corp.*

1034. Cleaning
Bulletin on equipment for cleaning and pickling of shell cases and other ordnance items. *Alvey Ferguson*

1035. Cleaning
12-page Bulletin 68 deals with factors to consider in selecting metal cleaning equipment. *Despatch Oven*

1036. Cleaning
32-page booklet on alkaline, solvent, emulsion, acid phosphate cleaning. *E. F. Houghton*

1037. Cleaning Aluminum
Set of seven data sheets on cleaning and finishing of aluminum. *Pennsalt*

1038. Cleaning Stainless
8-page booklet on care and cleaning of stainless steels. *Republic Steel*

1039. Cobalt Alloy
12-page booklet, "Haynes Alloy No. 25", tells of the unique properties of this cobalt-base alloy. *Haynes Stellite*

1040. Cold Finished Bars
Engineering bulletin, "New Economies in the Use of Steel Bars". *LaSalle Steel*

1041. Cold Rolled Steels
32-page booklet on stainless, alloy and carbon spring steels, and other specialties. Melting, temper, finishes. *Crucible Steel*

1042. Compressors
12-page bulletin 126-A on application of turbo-compressors to oil and gas-fired equipment used in heat treating, agitation, cooling, drying. Performance curves, capacities. *Spencer Turbine*

1043. Continuous Annealing
Article on continuous production annealing of screws, bolts, rivets. *Sunbeam Corp.*

1044. Controller
12-page catalog 53-10 on stack-type pneumatic controllers for process variables. *Fischer & Porter*

1045. Copper Alloys
New 48-page book contains tables of alloys with composition, typical uses, general, working, mechanical, electrical properties, hardness, ASTM specification numbers. *Revere*

1046. Copper Alloys
64-page book on free-cutting brass, copper and bronze. *Chase Brass*

1047. Corrosion Resistance
20-page bulletin on copper alloys for corrosion resistance. Table gives applicability in 150 media. *Ampco*

1048. Crystal Models
Folder describes unique kit for constructing crystal models. *Harshaw*

1049. Cutting Oil
Facts on more efficient and economical plant operation through use of right lubricants described in "Metal Cutting Fluids" booklet. *Cities Service*

1050. Cutting Oil Chart
Selection chart for seven classes of metal in nine machining operations. *Aldridge Industrial Oils*

1051. Decarb Test
Simple test for decarburization described in Tips and Trends. *Ajax Electric*

1052. Descaling Stainless Steel
Bulletin 25 on descaling stainless steel and other metals in molten salt. *Hooker Electrochemical*

1053. Dew Point Control
Bulletin No. 21-C on instrument which indicates, records and controls dew point automatically. *Ipsen*

1054. Die Steel
Bulletins on air-hardening, high-carbon, high-chromium die steel containing sulphide additives. *Latrobe*

1055. Ductile Iron
Reprints on engineering applications of ductile iron and its significance to the foundry industry. *Youngstown Foundry & Machine*

1056. Electric Furnaces
Bulletin on rotary-hearth electric furnaces, with maximum operating temperatures of 1800° F. and 2500° F. for hardening, normalizing, drawing and pack carburizing. *General Electric Co.*

1057. Electric Furnaces
Brochure on electric heat treating, melting, metallurgical tube, research and sintering furnaces. *Pereny Equipment*

1058. Electric Furnaces
Booklet on four types of electric heating elements and their methods of mounting. *Holcroft*

1059. Electrodes
12-page bulletin on carbon-steel electrodes for use with inert gas shields. *Air Reduction Sales*

1060. Electroplating
8-page bulletin on rectifiers for cleaning, polishing, electroforming, electroplating and anodizing. *Ther Electric & Machine Works*

1061. Electropolisher
Bulletin on theory and practice of electrolytic polishing of metallurgical samples. Description of electropolisher. *Buehler*

1062. Extrusion
16-page bulletin on Koldflo extrusion of parts in one operation. Step-by-step procedure. *Mullins Mfg. Corp., Koldflo Div.*

1063. Ferro-Alloys and Metals
104-page book gives data on more than 50 different alloys and metals produced by the company. *Electro Metallurgical*

1064. Finishing
52-page book "Advanced Speed Finishing" describes equipment for deburring and finishing. *Almco Div.*

1065. Flame Hardening
20-page booklet on precision flame hardening machine with electronic control. Details of operation and applications. *Cincinnati Milling Machine*

1066. Flow Meters
24-page manual on application and installation of indicating flow meter. *Meriam Instrument*

1067. Flow Meters
Bulletin 201 on flow meter for gas used in heat treating. *Waukee Eng'g.*

1068. Forgings
94-page book on die blocks and heavy-duty forgings. 20 pages of tables. *A. Finkl & Sons*

1069. Forming Dies
Folder on styles of forming dies for stainless heads—in wide range of sizes and gages. *Carlson*

1070. Forming Equipment
Bulletin on machinery and equipment for cold roll forming. *American Roller Die*

1071. Foundry
36-page illustrated booklet dealing with foundry products, procedures and craftsmanship. *Lebanon Steel Foundry*

1072. Foundry Equipment
New 16-page bulletin on various models of mold and core machines, their operation and installation. *Beardsley & Piper*

1073. Foundry Refractories
30-page catalog of refractories for foundry use includes sections on cupola block manufacture, ladle refractories, slag and breast block, etc. *Laclede-Christy*

1074. Fuel Gas
Bulletin on "Pyrofax" gas for cutting, brazing, metallizing, flame hardening, carburizing and heat treating. *Pyrofax Gas Co.*

1075. Furnace Belts
44-page catalog describes metal belts for quenching, tempering, carburizing and other applications. *Ashworth Bros.*

1076. Furnace Charging
12-page brochure on eight models of charging machines for heating and melting furnaces. *Salem-Brosius*

1077. Furnace Construction
12-page bulletin on thin-wall construction for furnace enclosures. Engineering drawings. *Bigelow-Liptak*

1078. Furnace Controls
Catalog 53-1 on furnace and oven controls including temperature controllers, recorders and indicators and safety control equipment. *Minneapolis-Honeywell*

1079. Furnace Controls
22-page booklet on instruments and controls for heat treating furnaces. *Hays Corp.*

1080. Furnace Fixtures
16-page catalog on baskets, trays, fixtures and carburizing boxes for heat treating. 66 designs. *Stanwood Corp.*

1081. Furnaces
Folder describes complete set-up for heat treatment of small tools, including draw furnace, quench tank and high temperature furnace. *Waltz Furnace*

1082. Furnaces
40-page book describes gas and electric furnaces and applications. Four basic types of atmospheres. Glossary of heat treating terms. *Westinghouse*

1083. Furnaces
12-page brochure on car furnaces of special and conventional design. *Jet Combustion*

1084. Furnaces
High temperature furnaces for temperatures up to 2000° F. are described in bulletin. *Carl-Mayer Corp.*

1085. Furnaces
Bulletin No. 200 on multi-burner heat treating furnace. *Am. Gas Furnace*

1086. Furnaces, Heat Treating
32-page catalog no high-speed gas furnaces for heat treating carbon and alloy steels; also pot furnaces for salt and lead hardening. *Charles A. Hones*

1087. Furnaces, Heat Treating
Catalog on furnaces for tool room and general purpose heat treat. *Cooley*

1088. Furnaces, Heat Treating
Bulletin on fuel and electric furnaces for heat treating. *Dempsey*

1089. Furnaces, Heat Treating
12-page bulletin on conveyor furnace,

radiant tube gas heated, oil or electrically heated. *Electric Furnace Co.*

1090. Gear Hardening
Folder on application of induction heating to high-production hardening of gears. *Westinghouse*

1091. Globar Furnaces
Bulletin 153 describes nine types of furnace using silicon carbide heating elements for temperatures to 2600° F. *Hevi Duty*

1092. Gold Plating
Folder on salts for bright gold plating. Also lists equipment needed. *Sel-Rex*

1093. Graphite Electrodes
Vest-pocket notebook containing 90 pages of information on electric furnace electrodes and other carbon products. *Great Lakes Carbon Corp.*

1094. Graphitization
12-page booklet discusses graphitization from the standpoint of temperature, chemical composition, deoxidation practice, pre-welding microstructure, welding conditions, post-weld heat treatment, stress and strain. *Edward Valves*

1095. Handling Devices
Pamphlets on clamps for lifting and handling. Their application to various industries. *Merrill Bros.*

1096. Hardening Stainless
24-page "Story of Malcomizing" describes surface hardening of stainless steels. *Lindberg Steel Treating Co.*

1097. Hardness Tester
Booklet describes two models of Penetrascope hardness testers. *C. Tennant*

1098. Hardness Tester
20-page bulletin on use of portable hardness testers and accessories. *Ames Precision Machine*

1099. Hardness Tester
4-page bulletin on Brinell hardness tester weighing 26 lb. for portable and stationary use. *Andrew King*

1100. Hardness Tester
20-page book on hardness testing by Rockwell method. *Clark Instrument*

1101. Hardness Tester
Catalog of testers for normal hardness, superficial testing, accessory and special testing and micro and macro hardness testing. *Wilson Mechanical Instrument*

1102. Hardness Tester
Data on portable hardness tester for Rockwell readings. *Riehle*

1103. Heat Processing
Bulletin answers questions: what is to be heated, what sections are to be heated, why the material is to be heated, to what temperature and for how long. *Selas*

1104. Heat Resistant Alloy
10-page article on how to get best service out of standard grades of heat resisting alloys by proper selection. *Rolled Alloys*

1105. Heat Resistant Alloy
Pyrasteel bulletin describes chromium-nickel-silicon alloy for service economy in resisting oxidation and corrosion to 2000° F. *Chicago Steel Foundry*

1106. Heat Resistant Alloy
Bulletin No. 1 on HR-3 (37% Ni, 17% Cr) cast alloy for parts subject to corrosion and high temperatures. *Standard Alloy*

1107. Heat Treating
Bulletin 14-T on ovens for heat treatment of aluminum and other low-temperature processing. *Young Bros.*

1108. Heat Treating
Handy, vest-pocket data book has 72

pages of charts, tables, diagrams and factual data on steel specifications, heat treatments, etc. *Sunbeam*

1109. Heat Treating
Catalog N-35 on furnaces for hardening high speed steel. *Sentry Co.*

1110. Heat Treating
56-page "Heat Treating Alloy Steels". *Republic Steel*

1111. Heat Treating
Bulletin 850 on shaker-hearth furnace for bright carburizing, carbonitriding, hardening. *Hevi Duty Electric*

1112. Heat Treating
Data on how to heat, quench, wash and temper automatically. *Metalwash Machinery*

1113. Heat Treating Ammonia
24-page "Guide for Use of Anhydrous Ammonia" describes heat treating and other metallurgical uses. *Nitrogen Div.*

1114. Heat Treating Baskets
12-page bulletin on wire mesh baskets for heat treating and plating. *Wiretex Mfg.*

1115. Heat Treating Equipment
New folder on carburizing boxes, trays, heat treat fixtures and baskets. *Misco*

1116. Heat Treating Fixtures
24-page catalog B-8 on muffles, retorts, baskets, other fixtures for heat treating in gas or salt baths. *Rolock*

1117. Heat Treating Fixtures
Folder shows 21 examples of heat treating fixtures, trays, baskets, retorts. *Allied Metal Specialties*

1118. Heat Treating Fixtures
24-page catalog on heat and corrosion-resistant equipment for heat treating and chemical processing. 30 classifications of equipment. *Pressed Steel*

1119. Heat Treating Guide
Chart guide constructed on slide rule principle for simplified hardening and drawing of tool steels. *Carpenter Steel*

1120. Heat Treating Pots
6-page bulletin lists sizes available in Thermalloy. Suggestions on increasing service life. *Electro-Alloys*

1121. Heat Treating Pots
Bulletin 110 gives data on sizes and shapes of cast nickel-chromium solution pots. *Fahralloy*

1122. Heat Treating Pots
Bulletin on heat and corrosion resistant metallized pots. *Eclipse Fuel Engineering*

1123. High-Alloy Castings
Bulletin 3150-G on castings for heat, corrosion, abrasion resistance. *Duraloy*

1124. High-Temperature Steels
87-page book on factors affecting high-temperature properties. 45 pages of data on tensile, creep and rupture properties of 21 high-temperature steels. *U. S. Steel*

1125. High-Tensile Steel
Bulletin on nickel-copper steel of low-alloy, high-strength type. *Youngstown Sheet and Tube*

1126. High-Vacuum Pumps
Data sheet on physical dimensions, operating data and performance curves for high-vacuum oil diffusion pumps. *Consolidated Vacuum Corp.*

1127. Identifying Stainless
Cardboard chart outlining systematic method for rapid identification of unknown or mixed stocks of stainless steels. *Carpenter Steel*

1128. Induction Heat Control
Data sheet on radiation pyrometer for direct measurement of work being induction heated. *Leeds & Northrup*

1129. Induction Heating
Bulletin on high frequency induction heaters. Application and equipment. *Electric Arc*

1130. Induction Heating
36-page catalog on high-frequency induction heating. *Lepel*

1131. Induction Melting
8-page article describes use of induction melting in improved technique for rotor-casting. *Ajax Engineering*

1132. Induction Melting
16-page booklet 14-B on high-frequency converter type furnaces for induction heating and melting of ferrous and non-ferrous metals. *Ajax Electrothermic*

1133. Industrial Radiography
Booklet gives recommendations on planning and construction of a betatron industrial radiograph laboratory. *Allis-Chalmers Mfg.*

1134. Instruments
Bulletin F-5633-1 on instruments for industrial process control. *Wheelco*

1135. Instruments
New 24-page catalog 5001 on industrial instruments and equipment. *Minneapolis-Honeywell*

1136. Insulation
40-page industrial products catalog on insulations, refractory products, and others. *Johns-Manville*

1137. Iron Powder
Bulletin on production of iron powder for flame cutting, scarfing, powder metallurgy, electronics and chemical applications. *Easton Metal Powder Co.*

1138. Laboratory Furnace
Box furnace with cooling chamber for use to 3100° F. described in bulletin GEA-4713. *General Electric*

1139. Laboratory Furnaces
Data sheets on complete line of laboratory furnaces for metallurgical operations. *Boder Scientific*

1140. Leaded Steel
Bulletin on analysis and advantages of cold finished leaded steel bars. *LaSalle Steel*

1141. Leaded Steel
8-page bulletin gives chemical composition, mechanical properties and case studies showing machining production rates of Ledloy, lead bearing steel. *Ryerson*

1142. Leaded Steel
Engineering memorandum on Ledloy-A, free machining, lead bearing steel. *Peter A. Frasse*

1143. Low-Alloy Steel
60-page book on high-strength low alloy steel, properties, fabrication and uses. *U. S. Steel*

1144. Low-Temperature Properties
48-page bibliography of characteristics of steels at low temperature covers 1904 to June 1953. *Inco*

1145. Lubricant
New catalog, No. 460, on how colloidal dispersions serve industry. *Acheson Colloids*

1146. Lubricant
New literature on anti-seize molybdenum disulfide lubricant. *Bel-Ray*

1147. Lubricant
8-page folder describes use of molybdenum disulfide lubricant in cold form-

High-Purity Fused Alumina Grains...
What Can They Do For You?

FUSED alumina, with its inherent properties of hardness, chemical stability and high density, is one of the most widely used electrochemically refined materials. It is produced in many forms. One of these, Norton 38 ALUNDUM* grain has proved successful for many applications demanding high purity. Electrically fused from Bayer-processed alumina, this white grain is shown by typical chemical analysis to be 99.49% pure Al_2O_3. It is insoluble in common solvents and extremely resistant to reduction. It is an amphoteric refractory and has high dielectric strength. Other characteristics include:

Melting point — about 3600°F.
Specific gravity — 3.94
Crystal structure — hexagonal system (rhombohedral division)
Hardness — 9.0 Mohs' scale
Index of refraction — 1.76 mean

Typical uses of 38 ALUNDUM grain are: pure oxides and sintered refractories, refractory cements, catalyst supports, heat exchange pebbles, wear-resistant parts, laboratory ware.

Other types of Norton fused alumina with unique combinations of properties which make them highly suitable for special requirements include:

38500 and 38900 AWIF ALUNDUM Grains

In these further refinements of 38 ALUNDUM grain, the terminal designations 500 and 900 indicate particle sizes. In the 38500 grain, average and maximum particle sizes are 19.5 microns and 50 microns, respectively; in the 38900 grain average and maximum particle sizes are 7.5 microns and 30 microns, respectively. Particle sizes are consistently very uniform. AWIF signifies "acid-washed and iron-free."

Although these grains have the same physical properties as 38 ALUNDUM grain, their special processing to remove objectionable elements results in unusually high purity. A typical chemical analysis reveals:

Al_2O_3 — 99.86% • Fe_2O_3 — .01 to .05%
SiO_2 — .01 to .05% • Na_2O — .01 to .08%
C — <.01% • pH — >4.1

Very good electrical resistance, high heat conductivity and inertness are further advantages of 38500 and 38900 ALUNDUM grains for applications in both the electrical and chemical fields. In addition to their use in electronic tubes, as illustrated, other possible uses include the manufacture of ceramic pieces, particularly electronic components where the inherent qualities of this extremely pure grain are of great value.

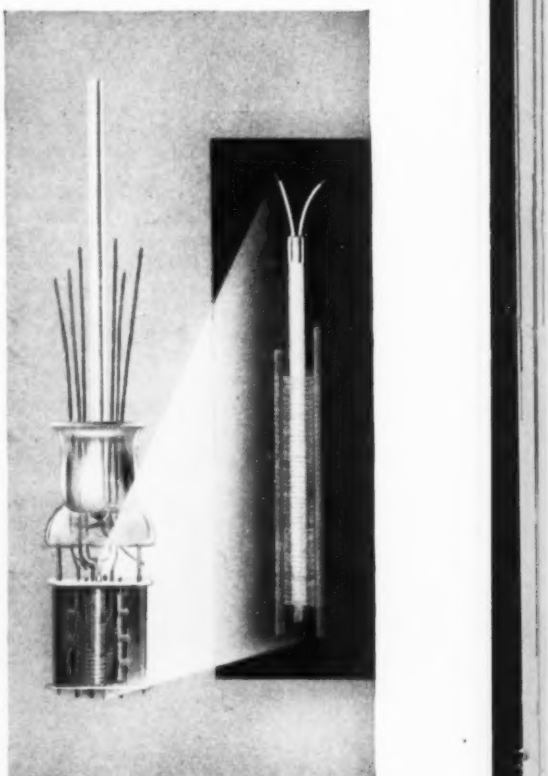
Other Norton Electrochemically Refined Materials

We made ALUNDUM grains the subject of this message. But we could just as well have chosen any of the long list of well known Norton electric furnace materials — CRYSTOLON* silicon carbide, MAGNORITE* magnesium oxide, NORBIDE* boron carbide, FUSED STABILIZED ZIRCONIA, and many others, including a number still undergoing research and development.

These high-melting materials which have varied applications in many fields, are also the basic ingredients of the famous Norton Refractory R's — refractories *engineered and prescribed* for the widest range of uses.

For Your Own Applications or Developments

Norton Company not only supplies these materials in their crude form, but has extensive facilities for processing and fabricating — and is ready to work with you in engineering materials to your particular requirements. A new booklet "Norton Refractory Grain Electrochemically Refined" contains detailed information on these interesting materials. NORTON COMPANY, 328 New Bond Street, Worcester 6, Mass.



IN ELECTRONIC TUBES Norton 38500 or 38900 ALUNDUM fused alumina grain is used to coat heater filament tubes (shown enlarged). The grain is put in suspension and the filament is drag coated, spray coated or electrically deposited (cataphoresis).

NORTON
REFRACTORIES
Engineered... R... Prescribed

Making better products... to make other products better

*Trade-Marks Reg. U. S. Pat. Off. and Foreign Countries

ing, cold heading and other applications. Case histories. *Alpha Corp.*

1148. Lubricant Application
Bulletin on method of bonding dry molybdenum disulphide films on bearing surfaces by tumbling. *Alpha Corp.*

1149. Magnesium
42-page booklet on wrought forms of magnesium. Includes 31 tables. *White Metal Rolling & Stamping*

1150. Magnesium Castings
5-page reprint tells of new developments in making magnesium castings for aircraft needs. *Dow Chemical*

1151. Magnesium Extrusions
36-page bulletin gives values for moment of inertia, section modulus and radius of gyration of bars, tubing, angles, channels, tees, zees and other sections. *Dow Chemical*

1152. Master Alloys
Bulletin on custom-made alloys for remelt or reprocessing. *Cannon-Muskegon*

1153. Melting Aluminum
Bulletin 310 on furnaces for melting aluminum. *Lindberg Eng'g.*

1154. Metal Detector
Catalog on detector for any kind of metal or alloy. *RCA*

1155. Metallographic Equipment
12-page catalog E-29 describes bright-field equipment for visual observation and photography. *Bausch & Lomb*

1156. Meters and Controls
New 16-page Bulletin 17 on basic specifications for measuring, transmitting, receiving, interpreting and controlling 18 variables normally encountered in production. *Bailey Meter*

1157. Microhardness Tester
Bulletin describes the Kentron microhardness tester. *Torsion Balance Co.*

1158. Moly-Sulphide Lubricant
40-page booklet on Moly-sulphide lubricant gives case histories for 154 different uses. *Climax Molybdenum*

1159. Nitriding
48-page booklet on nitralloy and nitriding, including the new Floe process. Types of nitriding steels, surfaces not to be hardened, weldability. *Nitralloy Corp.*

1160. Nitrogen Atmosphere
Bulletin on generator for producing pure nitrogen with a controllable hydrogen content. *Baker & Co.*

1161. Nonferrous Tubing
Bulletin on seamless, brazed and lock-seam tubing in brass and copper. *H & H Tube and Mfg.*

1162. Nonferrous Wire
Folder gives wire gage and footgage chart and data on beryllium copper, phosphor bronze, nickel, silver, brass and aluminum wire. *Little Falls Alloys*

1163. Openhearths
Brochure on modern openhearth design and construction. *Loftus*

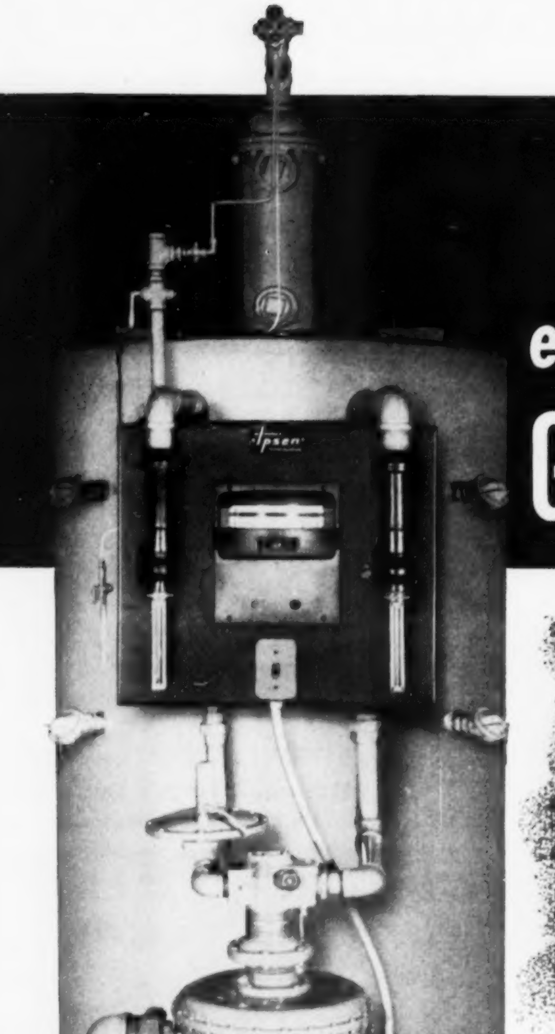
1164. Pickling Baskets
Data on baskets for degreasing, pickling, anodizing and plating. *Jelliff*

1165. Pickling Baskets
12-page bulletin on mechanical picklers, crates, baskets, chain and accessories. *Youngstown Welding & Eng'g*

1166. Pipe and Tubing
68-page book on pipe and tube making, answering many pertinent questions on

(*Continued on page 32-A*)

IPSEN
endothermic
GENERATORS



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A complete line of Ipsen Generators, gas-fired, with output capacities ranging from 250 to 5000 C.F.H. is now available with all of the proven features of other Ipsen electric endothermic units. Specific features of the gas-fired models include multi-jet burners and an inconel retort, automatic temperature control of water-cooled heat exchanger, double exhaust vents, and automatic protective devices that assure efficient operation within a safe temperature range.

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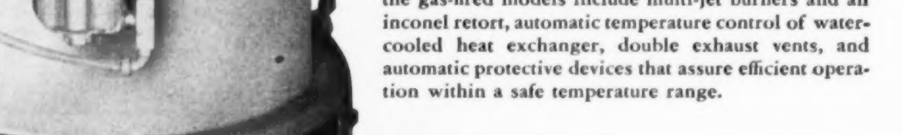

1206. Stainless Steel
44-page book gives detailed information on use of stainless steel in the chemical industries. *Crucible Steel*

1207. Stainless Steel
36-page bulletin on effect on properties of processing at different temperatures. *International Nickel*

1208. Stainless Tubing
28-page book on corrosion, uses and fabrication of stainless steel tubing. *Steel and Tubes Div., Republic*

1209. Steel 52100
New stock list on 52100 tubing, bars, and ring forgings. *Peterson Steels*

1210. Steel 52100
Data sheet on high-purity 52100 steel, made by vacuum melting. *Vacuum Metals*

1211. Strip Mill Equipment
Bulletin on units and assemblies for cleaning, annealing, pickling and drying strip. *W. S. Rockwell*

1212. Subzero Freezer
Data on chest for use down to −95° F. for production use and testing. *Revco*

1213. Subzero Tests
62-page bulletin on equipment for low-temperature tests. *Bowser Technical Refrigeration*

1214. Temperature Control
36-page bulletin P 1245 on new electronic instruments for recording and indicating variables. *Bristol Co.*

1215. Tempering
Bulletin 1E-11 on tempering and other applications in liquid baths. *Kemp*

1216. Tempilstiks
"Basic Guide to Ferrous Metallurgy", a plastic laminated wall chart in color. *Claud S. Gordon*

1217. Testing Machines
Universal testing machines and equipment are diagramed, described and illustrated in 20-page Bulletin 43. *Tinius Olsen*

1218. Testing Machines
32-page catalog on hydraulic testing machines. 10 models described; also accessories. *Riehle*

1219. Textured Metal
16-page booklet on advantages and applications of textured metal. *Rigidized Metals*

1220. Thermocouples
44-page catalog EN-S2 describes couples

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955	980	1005	1030	1055	1080	1105	113
956	981	1006	1031	1056	1081	1106	113
957	982	1007	1032	1057	1082	1107	113
958	983	1008	1033	1058	1083	1108	113
959	984	1009	1034	1059	1084	1109	113
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968	993	1018	1043	1068	1093	1118	114
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971	996	1021	1046	1071	1096	1121	114
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973	998	1023	1048	1073	1098	1123	114
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and assemblies for general application and for special plant and laboratory uses. Tabular data on accuracy and limits of couples. *Leeds & Northrup*

1221. Tin
20-page booklet describes mining of tin and its present use by American industry. *Malayan Tin Bureau*

1222. Titanium Tubing
Bulletin No. 42 on properties, applications and advantages of titanium tubing. *Superior Tube Co.*

1223. Tool Steel
60-page booklet on high-speed, hot work, cold work, shock resisting, carbon and low-alloy tool steels. *Jessop*

1224. Tool Steel
Bulletin on precision-ground oil-hardening and air-hardening tool steel flat stock. *Jessop*

1225. Tool Steel
20-page booklet on selection of proper tool steel support material for use with carbide tools. *Allegheny Ludlum*

1226. Tool Steel Failures
124-page book, "Tool Steel Trouble Shooter", analyzes 107 tool failures and assigns causes as among tool design faults, tool steel faults, improper heat treatment, mechanical and operational factors. *Bethlehem Steel*

1227. Tool Steel Selector
Twist the dial of the 9-in. circular selector and read off the tool steel for your application. *Crucible Steel*

1228. Tool Steel Tubing
4-page bulletin on high carbon steel small diameter tubing. Recommended heat treatments, chemical composition, mechanical properties, production limits, tolerances and applications. *Superior Tube*

1229. Tubing
52-page "Handbook of Seamless Steel Tubing." 26 pages of data. *Timken*

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46-page book on tube life in high-pressure high-temperature applications. Results of a great number of investigations of failures. *Babcock & Wilcox*

1231. Tungsten Alloy
Data on properties and uses of 95% tungsten alloy, balance nickel and copper. *Firth Sterling*

1232. Tungsten Electrodes
Folder on inert gas welding techniques using tungsten electrodes. *Sylvania Electric*

1233. Ultrasonic Cleaning
Folder on Sonogen ultrasonic generator for metal cleaning. *Branson*

1234. Vacuum Calculator
Slide rule for quick calculation of data necessary in vacuum engineering and processing—for instance, pump capacities and time to reach given vacuum. Pertinent conversion tables on back. *F. J. Stokes Machine*

1235. Vacuum Gage
Folder GEC 986 on molecular vacuum gage for measuring pressures without external detectors. *General Electric*

1236. Vacuum Metallurgy
Articles on commercial vacuum furnaces for metals and alloys and some aspects of vacuum melted metals. *National Research Corp.*

1237. Vacuum Pumps
24-page Bulletin V51 on high-vacuum pumps and accessories. *Kinney Mfg.*

1238. Valves
New 16-page catalog on two types of goggle valves for blast furnace and coke oven gas mains. *Salem-Brosius*

1239. Welding
Three bulletins on recently developed Fillerarc consumable - electrode gas-shielded welding process. *General Electric*

1240. Welding Alloy Steel
44-page Data Book 4D covers all types of welding of nickel alloy steels. *International Nickel*

1241. Welding Electrodes
New 24-page booklet on welding electrodes for stainless steels. Metallurgy of stainless steels, composition and uses of different electrode grades. *A. O. Smith*

1242. Welding Equipment
Catalog on Cadweld process and arc-welding accessories. *Erico Products*

1243. Zinc and Cadmium Plate
Technical data sheets on use of Lusteron salts for zinc and cadmium plating. *Chemical Corp.*

1244. Zirconium
26-page booklet gives physical, mechanical and chemical properties, present and potential uses, supply and prices of zirconium. *Zirconium Metals*

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(Continued from page 31)
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16-page instruction bulletin on bright silver plating process. *Hanson-Van Winkle-Munning*

1168. Plating
Bulletin CR-110-5 describes equipment, bath, operating conditions and control of high-speed chromium plating process. *United Chromium*

1169. Plating of Aluminum
Recent developments, factors affecting plating techniques, recommended procedures, in "Technical Advisor" No. 23. *Reynolds Metals*

1170. Precision Casting
Bulletin on how precision casting is done. Typical castings. *National Precision Casting Corp.*

1171. Precision Casting
44-page Catalog 53 covers every stage of the investment casting process. *Alexander Saunders*

1172. Precision Castings
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1175. Quenching
New catalog on two small self-contained quenching units. *Bell & Gossett*

1176. Quenching Oil
10-page book on new oils for the quenching process gives results on hot wire quench test and in plant operation. *Sinclair Refining Co.*

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1180. Radiography
Bulletin 400-310 on self-contained X-ray unit for mass production inspection of parts. *Westinghouse*

1181. Rare Earths
8-page Progress Report Number 1, "Rare Earths in Iron and Steel Melting". *Molybdenum Corp.*

1182. Refractories
12-page bulletin on six types of insulating brick, how to insulate, thermal data. *Harbison-Walker Refractories*

1183. Refractories
32-page booklet on plastic refractory and its use in soaking pits, car bottom furnaces, blast furnaces, openhearths. *Ramtite*

1184. Refractories
123-page handbook of refractories discusses research and quality control, standard and series shapes, high temperature specialties. *Walsh Refractories*

1185. Refractories
20-page booklet gives technical information on super refractories. *Refractories Div., Carborundum Co.*

1186. Refractories
Form 1409 on fused stabilized zirconia refractory for furnace linings, metal melting, other uses. *Norton Co.*

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Reprint on Current Refractory Practice as Applied in Copper Smelting. *Harbison-Walker Refractories*

1188. Refractory Cement
Bulletin discusses refractories and heat-resistant concrete. *Lumnite Div.*

1189. Refractory Mixes
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Data on properties, thicknesses required, costs, operation, applications. *Technic*

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24-page Bulletin 1053 on designing, forming and producing shapes from ferrous and nonferrous metals. *Roll Formed Products Co.*

1192. Rust Preventive
Pamphlet on Oilcoat T for prevention of rust in lubricating systems. *Gulf Oil*

1193. Rust Preventives
12-page bulletin on water-soluble rust-preventive. *Production Specialties*

1194. Salt Bath Furnaces
Data on salt bath furnaces for batch and conveyorized work. *Upton*

1195. Salt Baths
72-page catalog, 116 B, on operating principles and use of salt baths for 26 heat treating processes. *Ajax Electric*

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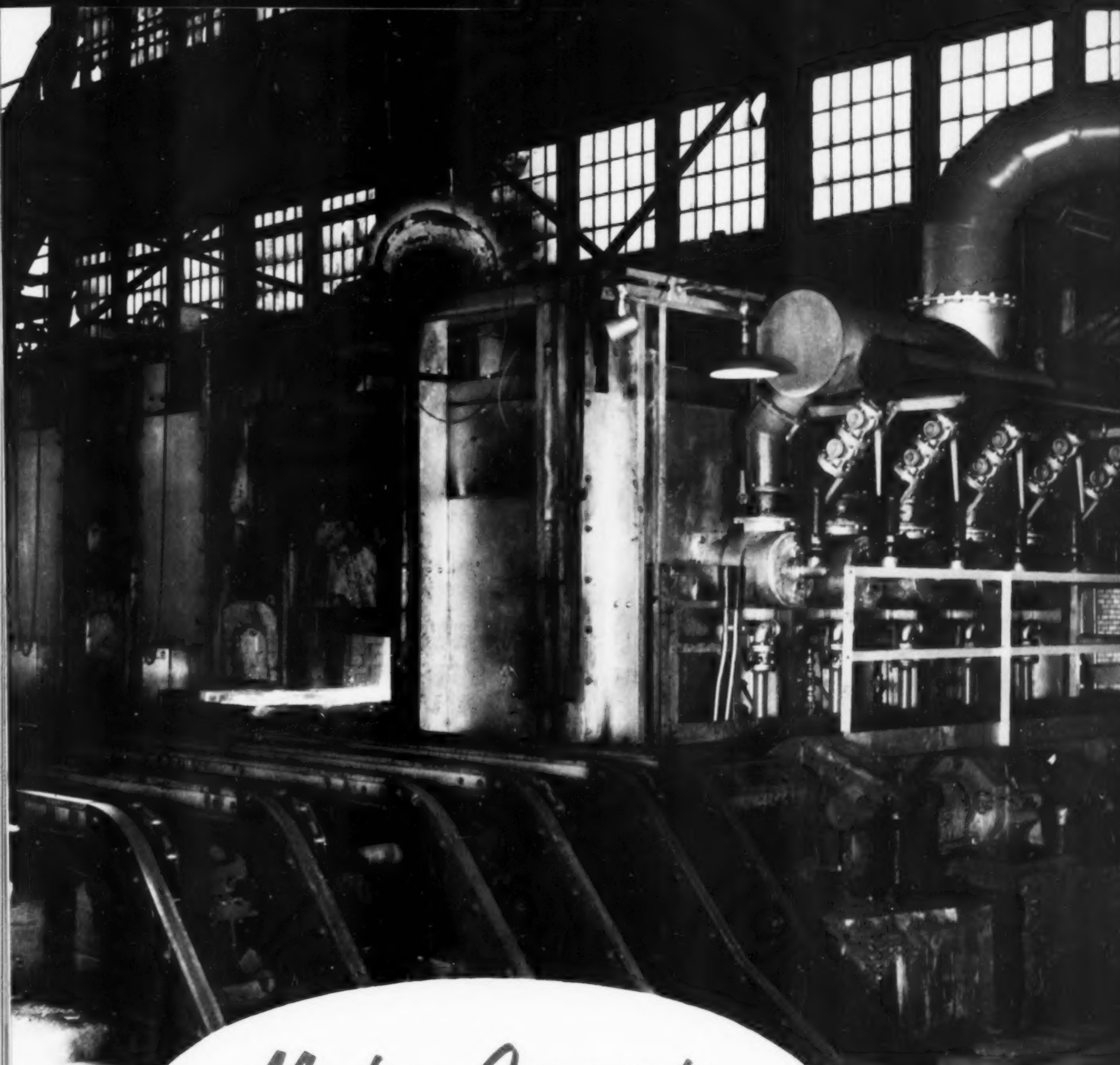

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Investigate the unique values of a 'dag' Colloidal Graphite *dry-film lubricant.*

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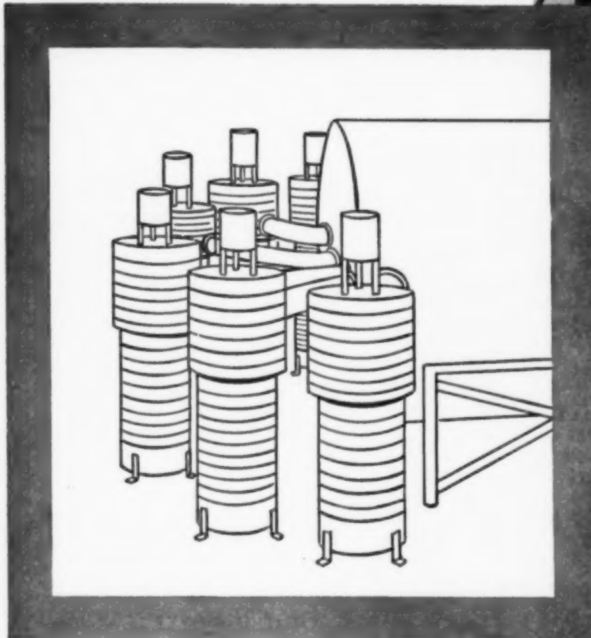

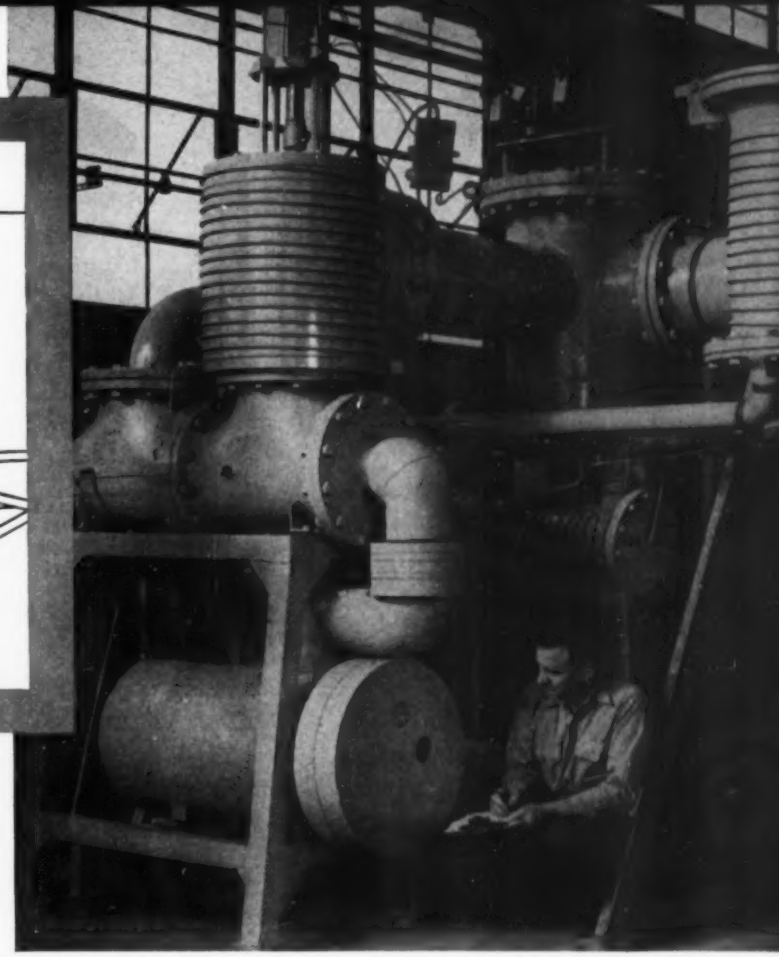

Which would you choose for *your* high vacuum furnace . . .

The wide jet clearances of this CVC type KB-1500 high vacuum pump suits it particularly to use on high vacuum furnaces. Its high-speed air removal rate is 2 lbs. per hour at 50 microns. It can produce an ultimate vacuum of 5 microns Hg, operating against a forepressure of .5mm Hg. A modified version, the type KS-4000, will produce an ultimate vacuum below .1 micron and has high pumping speed at 10 to 20 microns.

multiple small pumps or a *single* large pump combination?

The key to successful high vacuum melting and casting is LARGE CAPACITY *high vacuum pumping* in the *right* pressure range on a well designed flexible furnace.

The right range is anywhere from 300 microns (3×10^{-1}mm Hg) to 1 micron or lower absolute pressure—300 microns to take care of the inevitable burst of gas accompanying *any* melting operation—down to 1 micron or less to produce the final gas-free atmosphere so necessary to obtain high purity metals and permit adding the required alloying elements not possible at normal atmospheric pressure.

Only *CVC*'s Ejector or Diffusion-Ejector type high vacuum pumps will remove these large amounts of gas (from .5 to 13 lbs. of air per hour) over the entire pressure range, and generally do it with a single pump or at most two pumps in series.

Before you purchase a high vacuum melting and casting furnace in any size from 50 to 2000 lbs. of melt, contact *CVC*'s metallurgical and equipment design experts. ***Consolidated Vacuum Corporation, Rochester 3, N. Y.*** (a subsidiary of Consolidated Engineering Corporation, Pasadena, California).

CVC

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ROCHESTER 3, N.Y.

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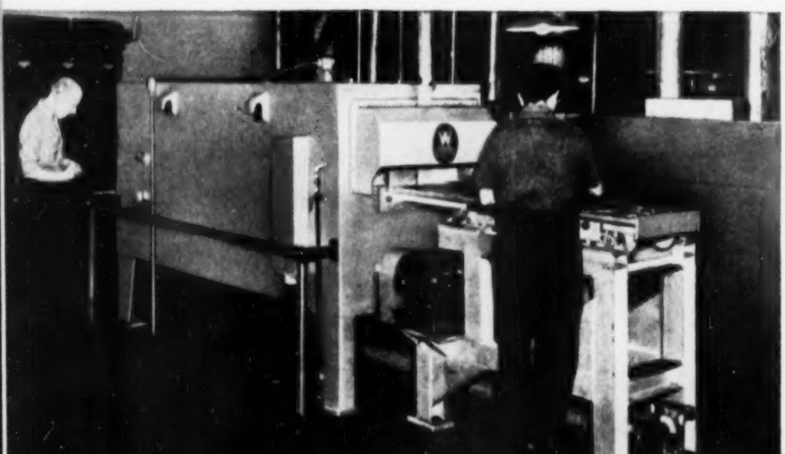
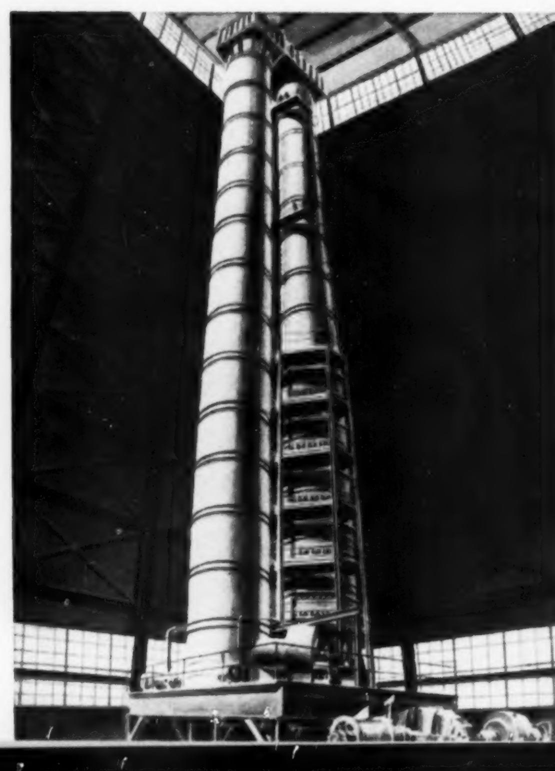
Mr. Emerich Bechtold, General Foreman of the Heat Treating Department, and a Gulf Sales Engineer examine the Sems as they emerge from a bath of Gulf Super-Quench.





FROM BOX TYPE TO ELEVATOR TYPE . . . this wide range of Westinghouse furnaces offers industry heat-treating units specially engineered for the smallest toolroom jobs on up to furnace capacities for massive parts treating. Accurate temperature control, uniform temperature distribution and low heat loss in Westinghouse furnaces assure high and constant quality level.

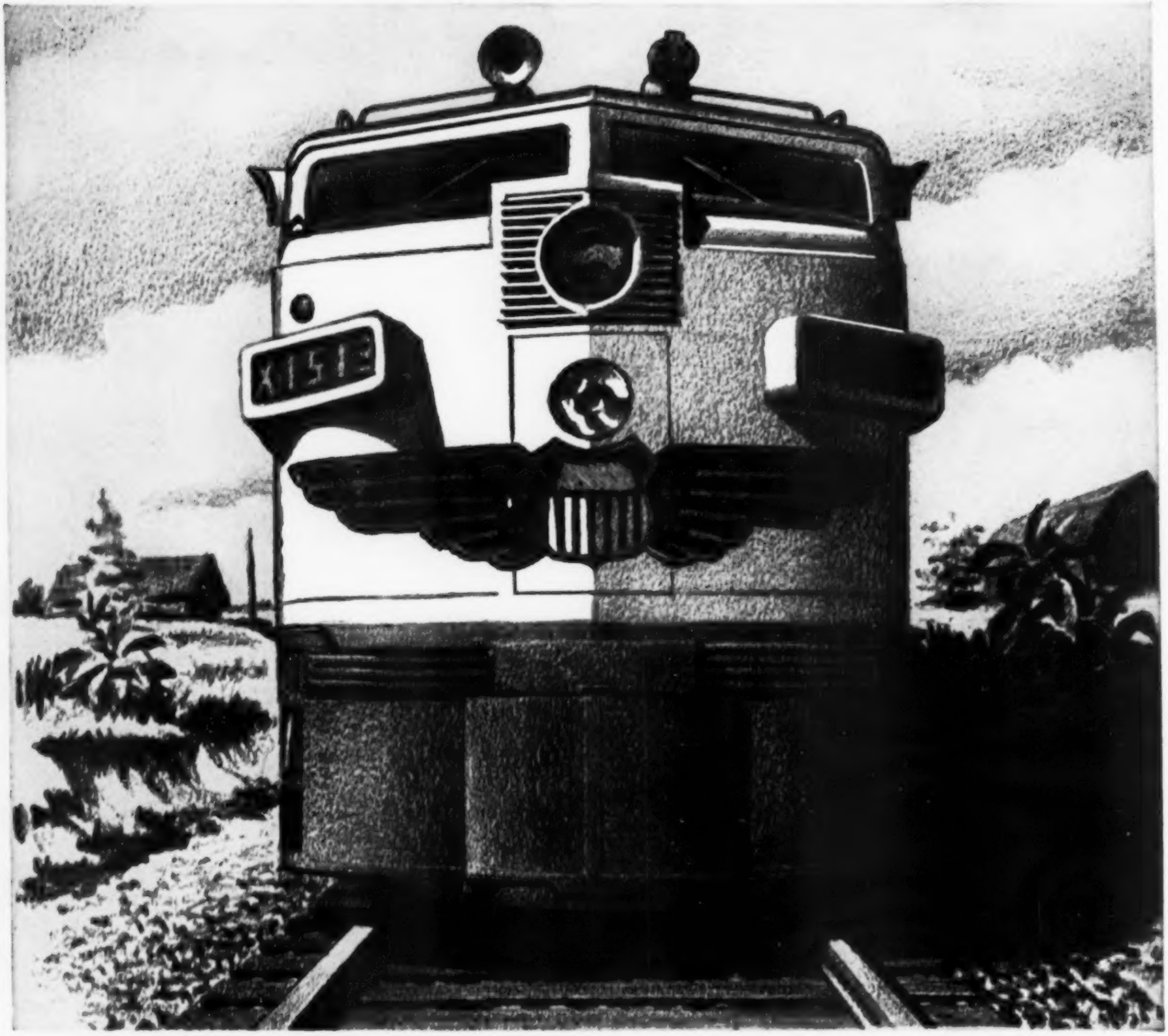
Sixty OK's keep TIMKEN® stainless steel forging bars uniform

THE test pictured above is only one of the sixty chemical tests every heat of Timken® stainless steel must pass. With all these checks for chemical composition, we can be sure that an analysis is *right*. That's why you can be confident that every bar in every order of Timken stainless steel forging bars is uniform in physical and chemical properties. Forgeability and response to heat treatment are uniform, too, so it isn't necessary to change shop practices with every shipment of material. Production time is saved, scrap loss is cut and you get a high quality finished product.

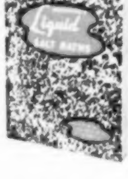
Call on our technical staff to help you choose the correct analysis of Timken stainless steel forging bars. And rely on our production department to get it to you when you want it. Want to know more about Timken stainless steel forging bars? Write for our technical bulletins. They're free, of course. The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".

YEARS AHEAD—THROUGH EXPERIENCE AND RESEARCH

SPECIALISTS IN FINE ALLOY STEELS, GRAPHITIC TOOL STEELS AND SEAMLESS TUBING



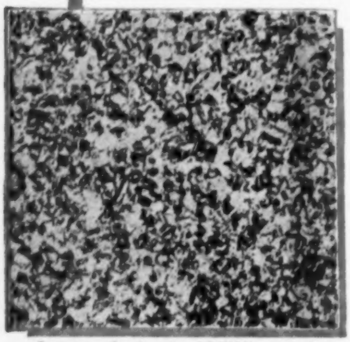

HOUGHTON
SALTS
HOUGHTON
KNOW-
HOW


Liquid
SALT BATHS

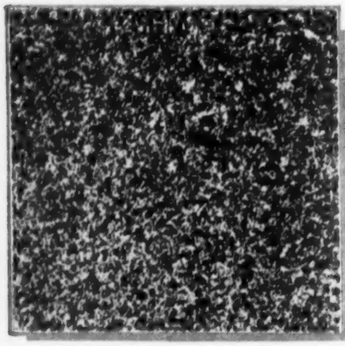
ASSOCIATION OF IRON and STEEL ENGINEERS
1010 EMPIRE BUILDING, PITTSBURGH 22, PENNSYLVANIA

Which Grain Size For Deep Drawing Brass?

by R. C. LeMay
Selas Corporation of America



Coarse—Grain size 0.020 mm obtained with conventional batch annealing. 75X



Fine—Grain size 0.010 mm max. obtained by high speed continuous annealing. 75X

Industry has for many years recognized the dependence of mechanical properties, as well as workability, upon grain size variations in brass. It is the accepted theory that with increasing grain size, tensile strength decreases and the per cent elongation increases. On this basis, it is usual practice to specify a coarser grain for deep drawing brass to provide the necessary degree of ductility.

The objectionable feature of a coarse grain for finishing work is the development of a rough "orange-peel" surface, which is difficult to buff. Conventionally processed brass for deep draws aims at a compromise between coarse grain for ductility and fine grain for improved surface.

The grain sizes shown above are representative for 85-15 red brass strip currently supplied the "eyelet" trade for deep drawn articles, such as lipstick containers and fountain pen caps, where high ductility and ease of buffing are prime requirements. The coarser grain is typical of material processed by batch annealing, in coils, on long time cycles involving many hours.

The fine grain is from material processed by a new, continuous method at the Somers Brass Company in Waterbury, Connecticut. In this operation a single strand of brass strip, moving at speeds up to 190 feet per minute, is heated to annealing temperature in but seconds and is then quickly cooled. The fine grain shown above is smaller than the minimum size (0.015 mm) appearing in the ASTM Standard Micrographs for Comparison of Grain Sizes.

A comparison of the mechanical properties for the two materials follows:

	Fine Grain	*Coarse Grain*
Annealing method	Continuous	Batch
Grain size, mm.	0.010 max.	.020
Tensile strength, psi	47500	44000
Elongation, %	40	40

(Data furnished by Somers Brass Co.)

The dual objectives of (1) fine grain for less buffing and (2) ample ductility for deep drawing, cannot be realized by conventional annealing practices, and, therefore, require a compromise between the two conditions. The development of a very fine grain by coil annealing requires prolonged holding periods at low temperatures, which does not assure complete recrystallization. The presence of a small amount of unrecrystallized metal limits the maximum ductility obtainable.

High speed annealing by the continuous method produces complete recrystallization at a high temperature and permits quick cooling to prevent grain coarsening by coalescence. This harder, more scratch-resistant, more ductile material, which requires only a simple color buff after draw, is superior to any other brass available for deep drawing buffed products.

The continuous process has been made possible through use of a Selas direct gas-fired furnace, requiring no costly, externally-prepared atmospheres to produce a uniform, clean annealed strip. The process, with heating times under ten seconds, is the fastest in the brass industry today. The furnace requires less floor space than other types of continuous strip annealers. Other advantages include low maintenance costs, reduced amount of material in process and operational flexibility for handling rush orders.

Selas Corporation of America
Philadelphia 34, Penna.

Save 5 ways with pallet boxed shipments

VANCORAM BRAND

FERROCHROMIUM, FERROSILICON, FERROMANGANESE BRIQUETTES

Now—
You can save time and money through . . .

1. EASIER HANDLING—Pallet boxes for Vancoram Briquettes and ferro alloys have been especially designed for safe, easy handling. Constructed of sturdy hard wood and tied with strong steel strapping—the chance of breakage is minimized.

2. MORE EFFICIENT STORAGE—The design and strength of Vancoram Pallet boxes permit safe multiple stacking indoors or out, which may not be feasible with more flimsy construction.

3. READY IDENTIFICATION — Pallet boxes of Vancoram Briquettes and ferro alloys are easily identified by the same plain marking and color-coding identification labels used on Vancoram Drums.

4. LESS CHANCE OF CONTAMINATION—Material confined to its own container rather than unwieldly bulk handling.

5. FASTER INVENTORY — Has the advantages of packed shipment in easy, quick inventory.

Besides briquettes, most other Vancoram ferro alloys are available in economical, easily-handled pallet boxes — another Vancoram service to you.

Producers of alloys VANCORAM metals and chemicals

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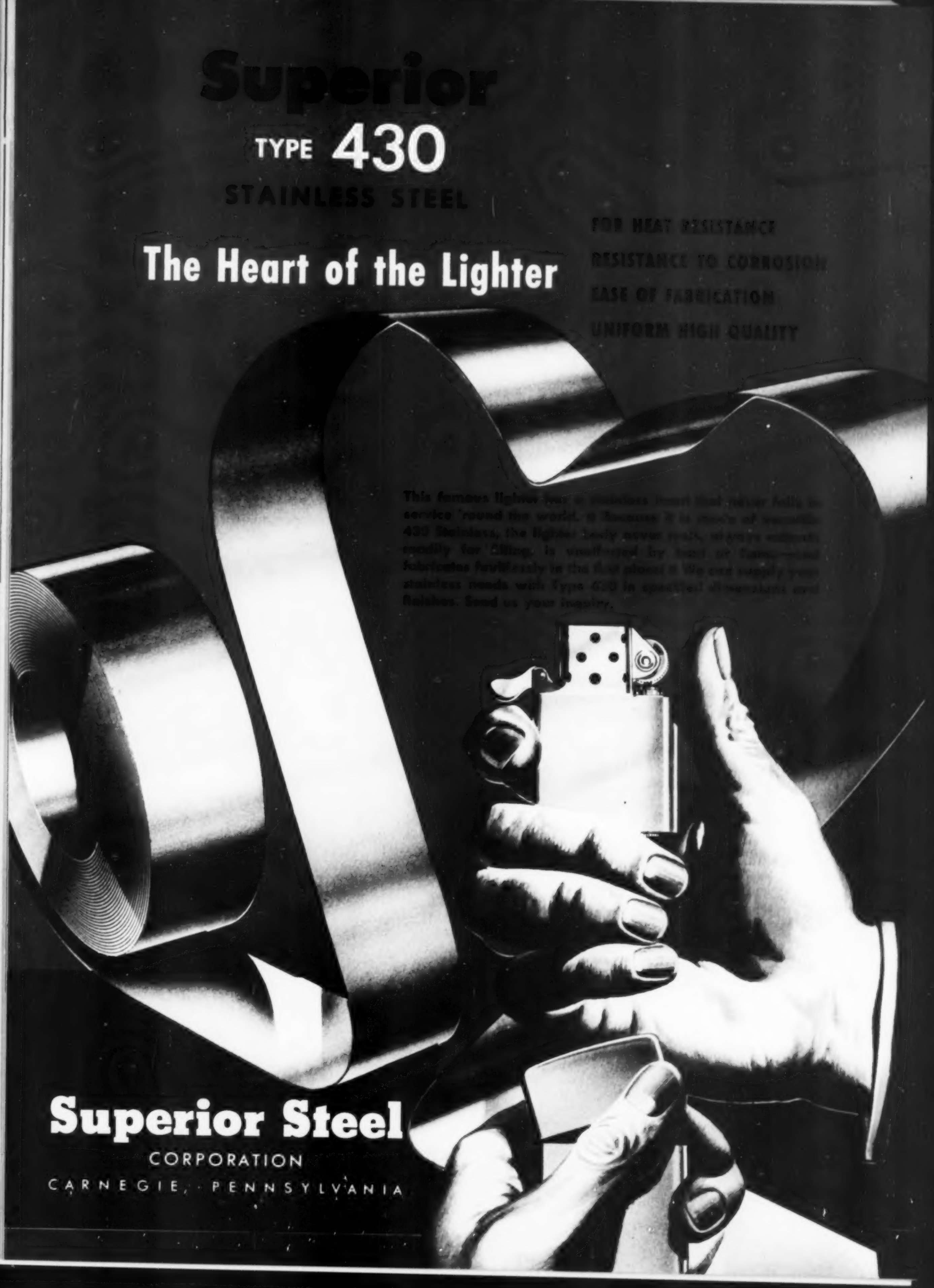

Superior
TYPE 430
STAINLESS STEEL
The Heart of the Lighter
FOR HEAT RESISTANCE
RESISTANCE TO CORROSION
EASE OF FABRICATION
UNIFORM HIGH QUALITY
Superior Steel
CORPORATION
CARNEGIE, PENNSYLVANIA

AMAZING POLISHING DISCOVERY!

A NEW BUEHLER POLISHING PAPER MAKES SAMPLE PREPARATION EASIER

Another Aid To The Metallographer

This paper combines the advantages of extremely fine grit size, rapid and clean cutting, long life, wet or dry operation. Use in place of 3/0 Emery Polishing Paper to produce better samples in less time.

ASK FOR A FREE SAMPLE

No. 1413-SW AB MICROCUT POLISHING PAPER DISCS, 8" diameter, wet or dry, grit 600 soft, per hundred $16.00

No. 1433-SW AB MICROCUT POLISHING PAPER DISCS, 8" dia. with ½" hole, wet or dry, grit 600 soft, per hundred $16.00

No. 1434-SW AB MICROCUT POLISHING PAPER SHEETS, 9" x 11", wet or dry, grit 600 soft, per hundred $20.00

No. 1435-SW AB MICROCUT POLISHING PAPER ROLL, 4" x 150', wet or dry, grit 600 soft, per roll $15.00

Buehler Ltd.

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Metal Progress

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THE BUYERS GUIDE FOR METALS ENGINEERS

NARACO FINISHING TIPS


Method of Racking

Chrome finishing for decorative hood ornaments—such as the "Rocket"—shown on this car is a plating problem . . . even to the experienced plater. NARACO'S know-how in engineering has answered this problem! They have designed an efficient rack, with accurately spaced robber bars, which produces a uniform chrome deposit free from any shading or burning.

You too can take a timely finishing tip from NARACO Plating Rack and Fixture Service by calling your nearest NARACO Plant—today!

NARACO

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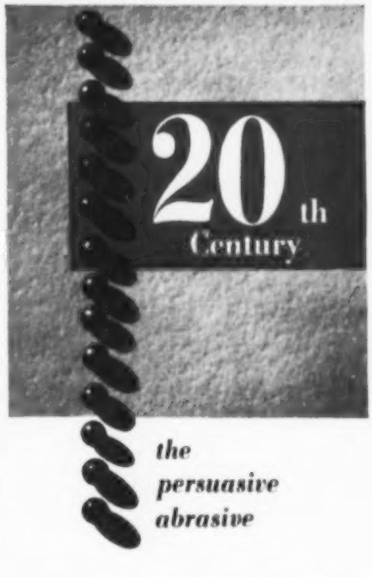
INDUSTRIAL RACK CO., 3462 N. San Fernando Road, Los Angeles, 63, Cal

LIST NO. 14 ON INFO-COUPON PAGE 64



the persuasive abrasive

Whether your concern is castings, forgings or metal parts, make 20th Century *Normalized shot and grit a part of your straight-line production operation.

The high uniformity and greater durability of 20th Century *Normalized give you maximum efficiency, increased economy, and a quality product.

New catalog No. 1153 on request.

THE CLEVELAND Metal Abrasive CO.

836 East 67th Street • Cleveland 8, Ohio
Howell Works: Howell, Michigan

*One of the world's largest producers of quality shot, grit and powder — Hard Iron — Malleable (*Normalized) — Cut Wire — Cast Steel (Realsteel)*

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- Economical
- No Change in Dimension
- Corrosion Resistant
- Perfect Uniformity
- Non-Technical

The Black Oxide Finish That Penetrates Iron & Steel Surfaces

**PURITAN MANUFACTURING CO.
WATERBURY, CONN.**

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RUST-LICK IN AQUEOUS SYSTEMS

Grade "C-W-25"

Non-flammable
Non-toxic
Aqueous Oily Film Protects Ferrous Parts for Long Periods Indoor Storage

Write for free sample and brochure
Specify Grade "C-W-25"

PRODUCTION SPECIALTIES, INC.
755 BOYLSTON STREET
BOSTON 16, MASS

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Plan to Attend the

METAL SHOW

Chicago

November 1 to 5

1954

Plan to Attend the

METAL SHOW

Chicago
November 1 to 5
1954

READERS' INFO-COUPON SERVICE, METAL PROGRESS
7301 Euclid Avenue, Cleveland 3, Ohio

Please send further information, as checked at the right, on the advertisements in the Bulletin Board with numbers I have listed below—

(Bulletin Board Item Number)	Send Catalog or Engineering Data	Send Price Info	Nearest Source of Supply
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ELECTRODE QUALITY ... has a direct bearing on the quality of *your* product; in many instances, it can materially affect your *cost.* National Carbon's graphite and carbon electrodes are, and always have been, the finest quality obtainable *anywhere.* We make this statement without reservation.

NEW PRODUCT DEVELOPMENT ... is basic in technological progress. National Carbon has *always* done the major part of this country's electrode research and development ... a share out of all proportion even to its outstanding leadership in the production and sale of these products. This is a matter of long-standing record.

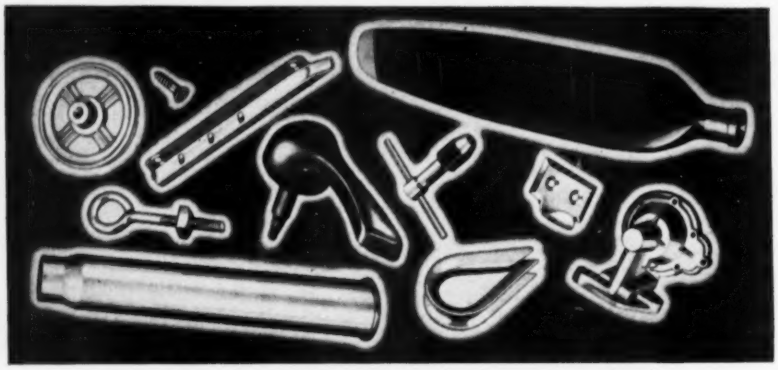
UNICHROME
Trade Mark

News about
COATINGS for METALS

Metallic . . . . Organic . . . . Decorative . . . . Protective

Extra opportunities to cut costs with zinc finishing

Wider choice of corrosion resisting chromate finishes being offered



Some of the many products finished in Unichrome Dips or Anozinc

CHROMATE treating still remains one of the best ways to finish zinc die castings or zinc plated steel. It strengthens corrosion resistance. It's an *easy* way to finish. It's economical. And time has proved its quality.

With such a combination of virtues offered in a finish, it pays designers, metal finishers and production men to review their products—and to evaluate the benefits of chromate finishing against their finishing requirements. Especially today—when the pressure is on to cut costs every possible way.

Through the unusually wide choice of finishes United Chromium provides, even greater benefits become possible. Here's why. A more economical dip solution may be chosen. Or a production advantage may be realized.

FOR EXAMPLE:

The right Unichrome Dip meant half the material consumption and longer solution life to one company.

Brighter finish on zinc plated hardware with less solution-waste was gained in another plant with still another compound.

Chromate treating of zinc plated steel shell cases done electrolytically with Anozinc is found best and cheapest in the long run by many producers.

HERE IS VARIETY

Unichrome chromate finishes offer a good color choice. Lustrous, clear bright finish or black—brassy yellow or olive drab—even brass-color—all these can be produced chemically by Unichrome Dip solutions.

Unichrome chromate finishes also satisfy production method requirements. Compounds are available for manual or automatic operation.

An exclusive electrolytic process, Anozinc* rounds out this complete line of conversion coatings. It's found especially economical in continuous, large run automatic production. This process permits finished parts to be handled while wet.

Write for more data.

**Trade Mark*

66% more chromium plating with same current source

One company, only able to plate *six* bumper bars per load, made a tremendous improvement by means of a simple change. They merely switched to a Unichrome SRHS Chromium Solution—and found that *ten* pieces of work per load could be covered with fewer rejections, all without any need for a larger current supply. That's good proof of the better coverage, higher efficiency and greater economy that "SRHS" offers. Write for Bulletin SRHS-2.

Sprayable plastisol builds up thick coating without sagging

First successful sprayable vinyl plastisols, the Unichrome Series 5300 Coatings can be applied even to vertical cold metal surfaces without sagging. Cured coating film up to 25 mils thick can be produced in a single application. Now even large areas can get the amazing protection against corrosion and wear offered by these non porous, chemical resisting, chip-proof coatings. Send for Bulletin VP-1.

HELPFUL HINTS

by "Mr. Cost Cutter"

For true economy in an organic finish, base your specifications on both quality and applied cost—rather than on misleading cost-per-gallon. Consider 3 flat black finishes for wrought iron, for example:

	applied cost/sq. ft.
Coating "A"	1.2 to 1.3¢
Coating "B"	0.8 to 0.9¢
Coating "C"	0.8 to 0.9¢

A Unichrome epoxy resin type finish, Coating "C" sells for twice as much per gallon as the other two, yet it not only gives best "mileage" but also a better looking, more durable and corrosion resistant finish.

UNITED CHROMIUM, INCORPORATED

100 East 42nd St., New York 17, N. Y.
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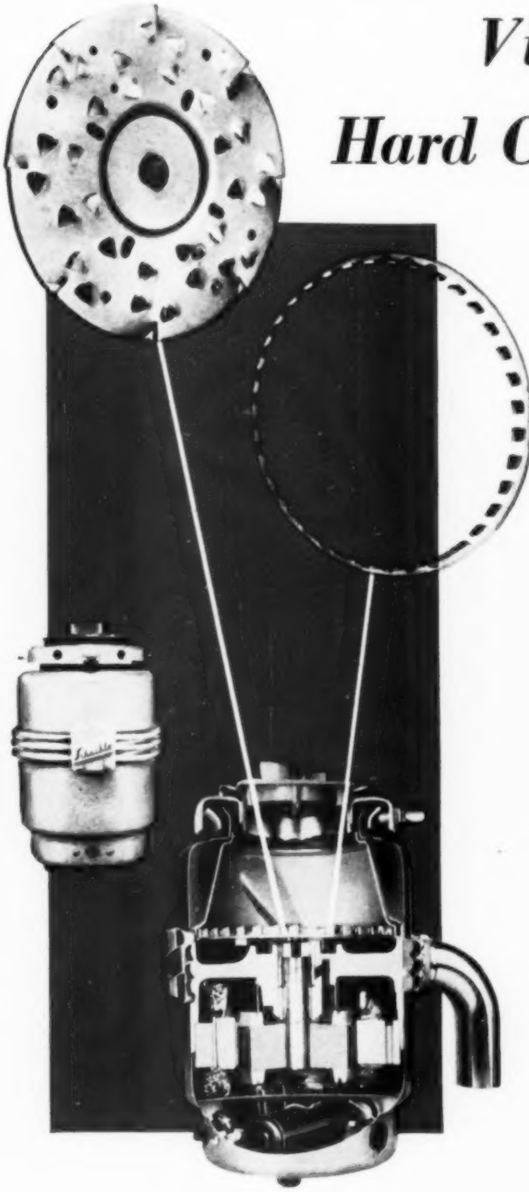
Chicago 4, Ill. • Los Angeles 13, Calif.
In Canada:
United Chromium Limited, Toronto 1, Ont.

The Schaible Story:



Vital Grinder Parts Hard Cased in Park-Kase 5-C

Maximum Hardness at LESS COST for Schaible Cutter Disc and Clip Ring!

At the Schaible Company the grinding elements used in the production of the Schaible Food-Waste Disposer are precision hard cased with water soluble Park-Kase 5-C. Result: a higher hardness which means longer life and greater efficiency for these fast-action grinding teeth . . . *in less time and at less cost.* Here's why:

The rapid and uniform case depth of Park-Kase 5-C liquid carburizer means fast, reproducible cases which can be held to close limits for accurate, dependable work at temperatures up to 1700°F. Park-Kase 5-C produces eutectoid carbon cases which contain enough nitrogen to be file hard after oil quenching. High penetration rates and ease of cleaning are combined for ideal carburizing conditions. Inexpensive, simple, and trouble-free . . . Park-Kase 5-C lowers production costs.

- Lightness of Original Charge and Reduction of Salt Drag-out Keeps Costs Down.
- Does Not Foam While Operating.
- Water Solubility Means Time Saved on Oil Quenched Work.
- Needs No Special Complicated Mixing Procedures.

Complete details of the Park-Kase 5-C Carburizing process covering all phases of its operations are described in a technical bulletin available by mailing the attached coupon.

The new grinding principle of the Schaible Food-Waste Disposer is shown here. Particle discharge size is positively controlled by reduction grating through horizontal milling action, impingement cutting and clipping. The snag-toothed cutter and the clip ring used in this process require hardness and toughness. Park-Kase 5-C gives these tools the necessary hard case for years of efficient, dependable service.

Fifth in a series of advertisements describing Park processes on the job

• Liquid and Solid Carburizers • Cyanide, Neutral, and High Speed Steel Salts • Coke • Lead Pot Carbon • Charcoal • No Carb • Carbon Preventer • Quenching and Tempering Oils • Drawing Salts • Metal Cleaners • Kold-Grip Polishing Wheel Cement

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PARK CHEMICAL CO.

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Send Free Bulletin Describing Park-Kase 5-C

Name__________ Position__________

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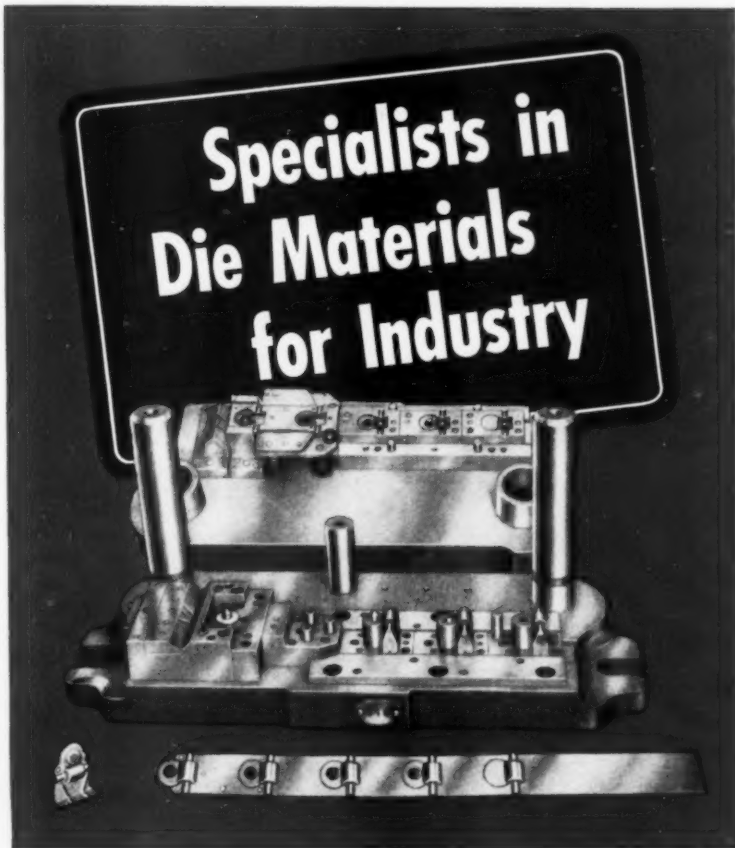

Attention:
Fastener Industry!
C.H.Q. Die Steel
makes
cold heading records

C.H.Q. solid die after 192,000 run.

A COMPLETE LINE...CARBIDE AND STEEL

● Firth Sterling offers manufacturers and fabricators the advantages of a *single* source of supply of materials for both tungsten carbide and steel shaping, forming, piercing, heading and other dies. This *complete* line, from famous Firthaloy, for maximum performance where carbide is a requirement, through almost one hundred grades of high speed and tool steels for cut-off knives, roll guides, die casings, forming rolls and similar applications, provides the exactly right material for each application. Maximum production at lowest cost is thus assured.

Standard items are available from warehouse stocks; others may be obtained from your local tool and diemaker.

Firth Sterling representatives are skilled in interpreting the needs of industry and in suggesting the exactly right steel or carbide for specific applications. Because they know and sell both, you can depend on their unbiased recommendations to result in better, more economical tooling.

A nationally known fastener manufacturer* recently made comparative tests of solid steel cold heading dies, under carefully controlled conditions, producing ⅜" square head machine bolts from 1020 steel on a Waterbury Farrel double stroke automatic.

Firth Sterling C.H.Q. came off with top honors and the highest production ever obtained by this manufacturer from any steel die . . . 192,045 both ends. (78,860 one end, 59 Rockwell C; 113,185 other end, 61 Rockwell C.) Standard competitive carbon steel dies produced only 50,000-60,000 both ends and ultimately failed by cracking axially. The C.H.Q. die wore oversize but longitudinally etched section revealed not even a hairline crack.

Ask for technical literature on C.H.Q.—or a Firth Sterling representative will discuss your die problems.

*(name on request)

Firth Sterling

—INC—

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PRODUCTS OF FIRTH STERLING METALLURGY

High Speed Steels	Sintered Tungsten Carbides
Tool & Die Steels	Firth Heavy Metal
Stainless Specialties	Chromium Carbides
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Zirconium

Another use of N·A·X HIGH-TENSILE STEEL in modern transportation equipment

Autos are *driven* aboard the new Evans 6-Car Auto-Loader under their own power. Loading and unloading goes faster—shippers save time and money.

Gives Greater Strength with Lighter Weight to new Evans 6-car Auto-Loader

Evans Products Company, Plymouth, Michigan, chose N-A-X HIGH-TENSILE steel for major parts of its revolutionary new 6-Car Auto-Loader.

An outgrowth of the original Evans 4-Car loader, this new unit increases pay load by 50 per cent—enables two freight cars to do the work of three.

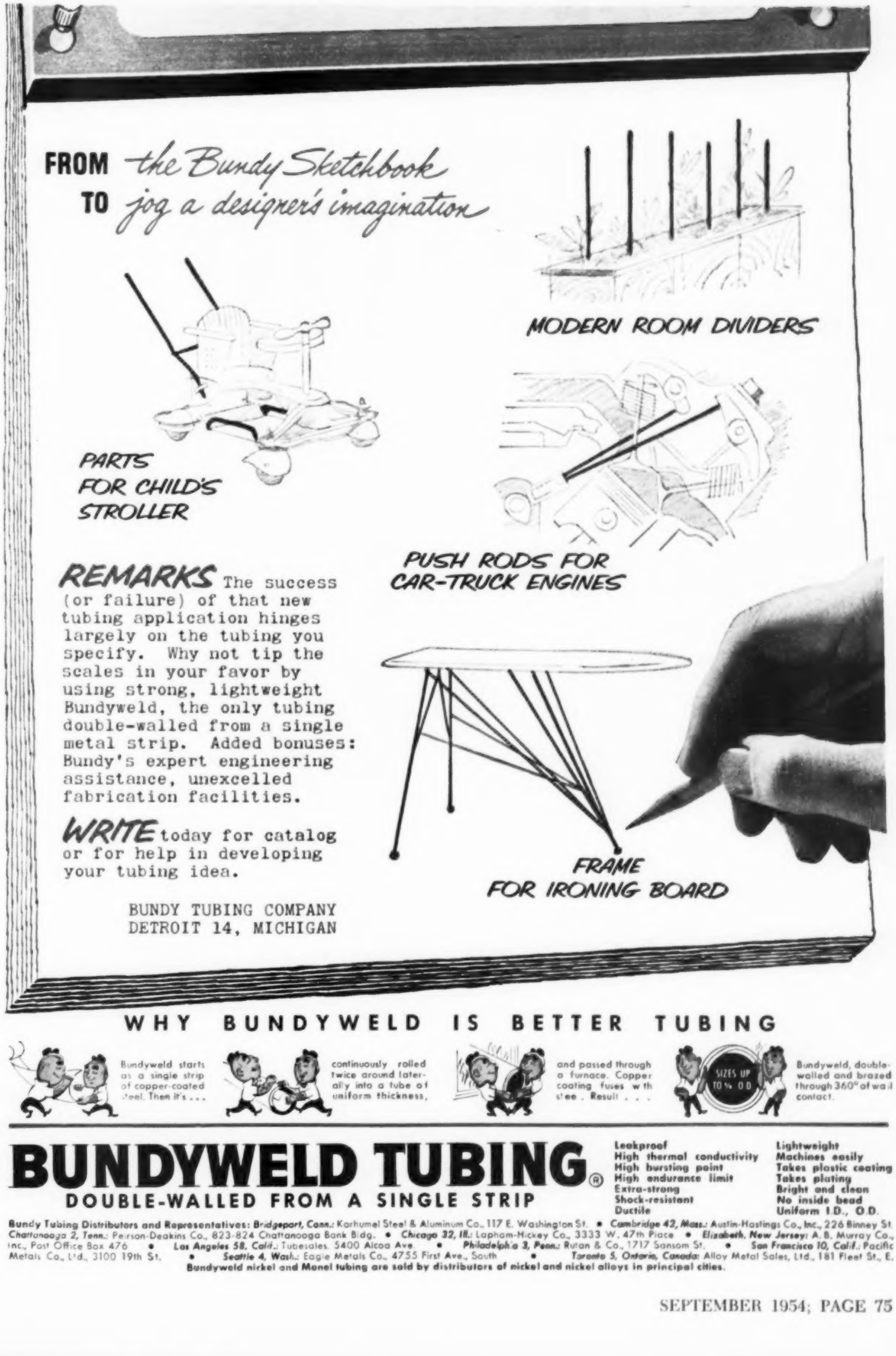
In designing the 6-Car Auto-Loader, Evans engineers specified N-A-X HIGH-TENSILE steel for all sheet, ramps, shear beams, and vertical members. This low-alloy steel has 50 per cent more strength than mild carbon steel, with greater resistance to corrosion with either painted or unpainted surfaces. In tests carried out at the Evans plant, N-A-X HIGH-TENSILE steel scored high on engineering and impact tests. This new unit was designed with advisory assistance and cooperation from both the A.A.R. Car Construction Committee and the I.C.C.

You, too, can benefit from the many advantages of N-A-X HIGH-TENSILE steel to make your product stronger, lighter in weight, and longer-lasting.

GREAT LAKES STEEL CORPORATION

N-A-X ALLOY DIVISION — Ecorse, Detroit 29, Michigan

NATIONAL STEEL CORPORATION


FROM the Bundy Sketchbook
TO jog a designer's imagination
MODERN ROOM DIVIDERS
PARTS FOR CHILD'S STROLLER
PUSH RODS FOR CAR-TRUCK ENGINES
REMARKS The success (or failure) of that new tubing application hinges largely on the tubing you specify. Why not tip the scales in your favor by using strong, lightweight Bundyweld, the only tubing double-walled from a single metal strip. Added bonuses: Bundy's expert engineering assistance, unexcelled fabrication facilities.
WRITE today for catalog or for help in developing your tubing idea.
FRAME FOR IRONING BOARD
BUNDY TUBING COMPANY
DETROIT 14, MICHIGAN
WHY BUNDYWELD IS BETTER TUBING
Bundyweld starts as a single strip of copper-coated steel. Then it's . . .
continuously rolled twice around laterally into a tube of uniform thickness,
and passed through a furnace. Copper coating fuses with steel. Result . . .
SIZES UP TO ⅝ O.D.
Bundyweld, double-walled and brazed through 360° of wall contact.
BUNDYWELD TUBING®
DOUBLE-WALLED FROM A SINGLE STRIP
Leakproof
High thermal conductivity
High bursting point
High endurance limit
Extra-strong
Shock-resistant
Ductile
Lightweight
Machines easily
Takes plastic coating
Takes plating
Bright and clean
No inside bead
Uniform I.D., O.D.
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Bundyweld nickel and Monel tubing are sold by distributors of nickel and nickel alloys in principal cities.

A prize recipe for brazing spuds

The principal ingredient is the low-temperature silver brazing alloy EASY-FLO. You simply place the spud in position with a ring of EASY-FLO wire around it, apply flux and heat. Logan Machine & Metal Stamping Co., Akron, Ohio, get excellent results with this recipe in brazing spuds in the oil pans that are part of an automatic automobile drive. Photos show how they do it.

Pans with spuds and EASY-FLO rings are placed in fixtures of 2-station induction heating unit. Brazing two at a time, production is 400 an hour. Under a 100-lb. torque test "the pan pulls apart first."

GET THIS METAL JOINING RECIPE BOOK...

It gives you tried and proved recipes for fast, low-cost metal joining that never fail. Write for a copy today. Ask for BULLETIN 20.

HANDY & HARMAN FOUNDED 1867 QUALITY SERVICE

ORIGINATORS OF EASY-FLO & SIL-FOS

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General Offices: 82 Fulton St., New York 38, N. Y.

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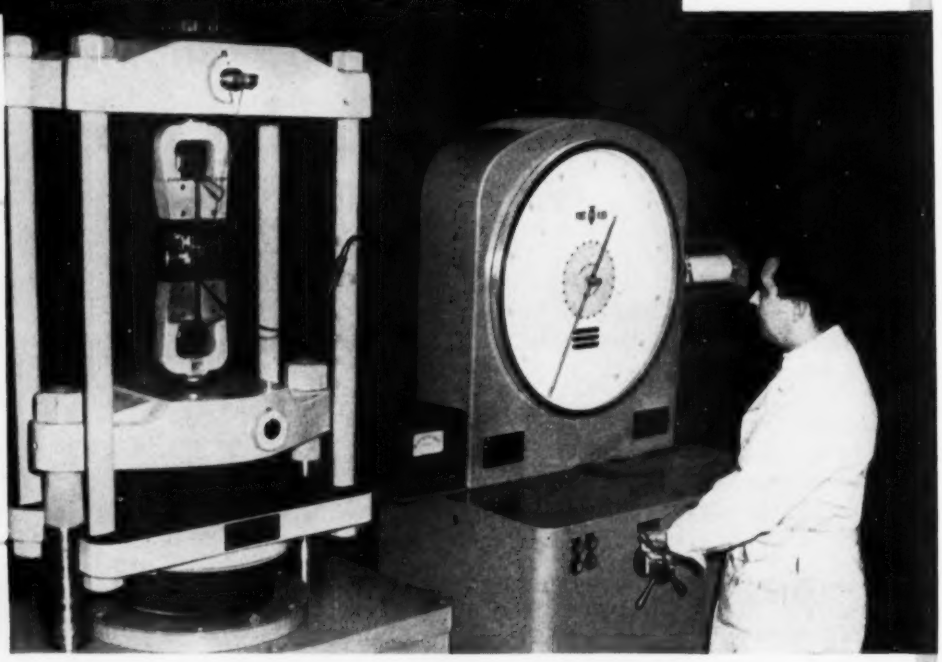
Fast, Accurate Testing

with an

OLSEN Super "L"



Olsen Super "L" U.T.M. used by Douglas Aircraft Company, Inc. El Segundo, Calif. Division for testing aircraft materials.

Featuring the incomparable SelecTrange electronic indicating system, Olsen Super "L" Universal Testing Machines are used in leading testing laboratories throughout the country for fast, accurate tension, compression and flexure testing of materials of every description.

Only the Olsen SelecTrange Indicating System provides 50 to 1 spread of testing ranges; instant change of ranges during test with the flip of a switch, without compensations of any kind; and many other important features that have literally revolutionized testing.

Electric extensometers used in conjunction with the Model 51 Electronic Recorder produce stress-strain curves with the Super "L". In addition, the 120,000 lb. capacity machine illustrated has a Crosshead Rate Indicator, mounted on the left of the control cabinet, which instantly shows the rate of crosshead movement in inches per minute on an electrical meter.

From every angle, the testing speed, ease of operation, and versatility of the Olsen Super "L" mean greater testing efficiency at remarkably low cost.

Details are given in Bulletin 47. Write for your copy today.

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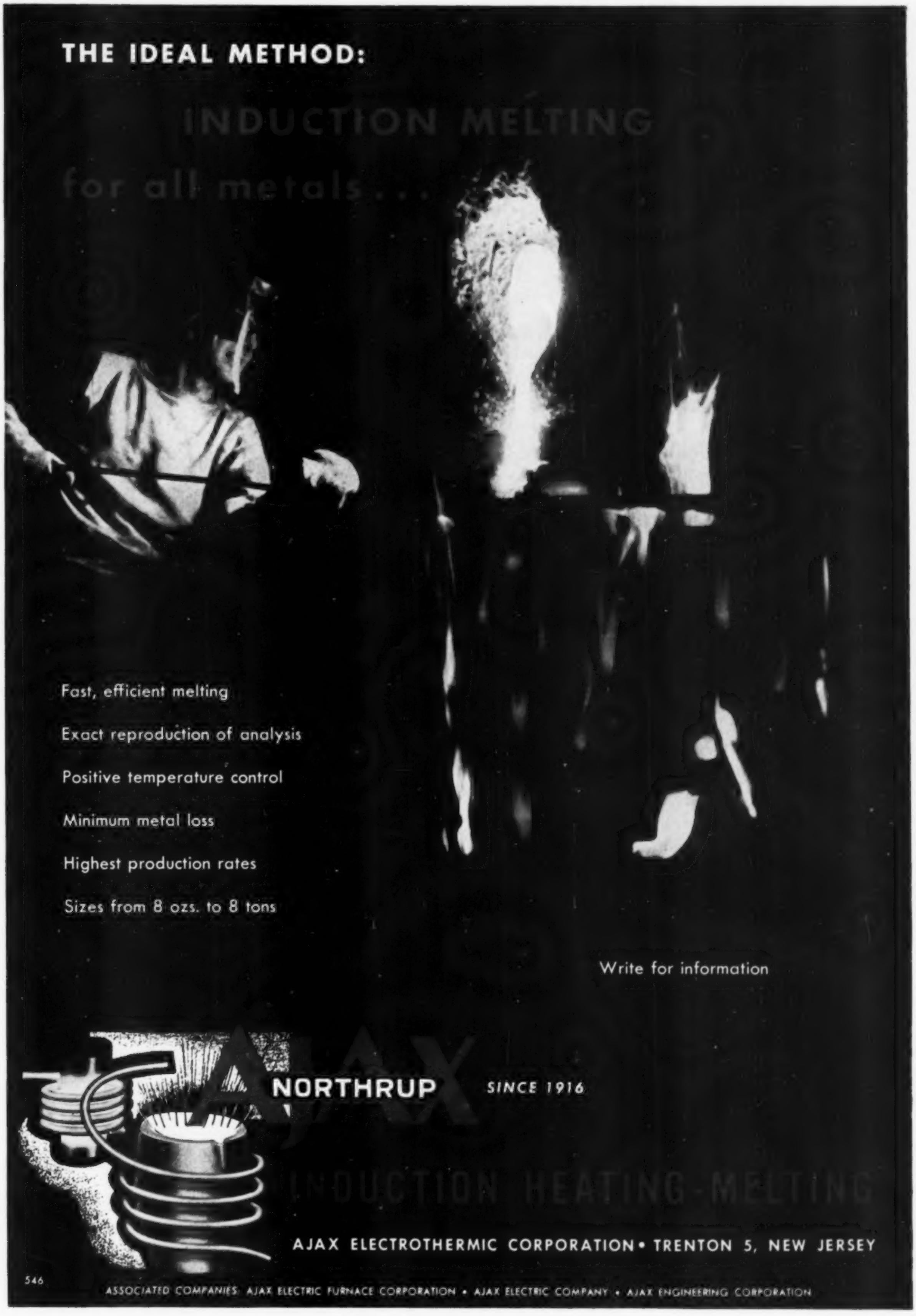
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Metal Progress
Volume 66, No. 3 September, 1954

Critical Points . . .

BY THE EDITOR . . .

Toolsteel Mill in Canada

Flew recently from Cleveland to London (Ontario, just across Lake Erie) to join many friends of Vanadium-Alloys Steel Co. in the opening of a Canadian subsidiary, thus becoming Atlas Steel Ltd. of Welland's competitor in the tool and die steel business up north. James P. Gill, president of the steel company and past-president of , said that ingots could be imported duty free from the home plant in Latrobe, Pa., whereas finished bars carried a 12¢ duty. Thus it is economical to install modern heating furnaces, hammers, presses, rolling mills and the usual straightening and finishing machinery and convert ingots to bars on the Canadian side.

Duty-free ingot is a sensible arrangement for the Canadians, who cannily let the Americans find the necessary high-grade raw materials and scarce alloying elements. George Roberts, vice-president (both of the steel company and of) also said that the Canadian staff—nearly all recruited locally—would be spared the big headaches in the business which reside in the melting department, and arise from the necessity of producing small amounts of special analyses and of highest uniformity and quality.

The toolsteel business in America is scattered among many small plants principally because of the "job-lot" nature of the business. Strong competition prevents any decree that high speed steel shall be 18-4-1, take it or leave it. Even this well-standardized analysis is produced on occasion in ±0.02% carbon ranges; Roberts said that five Vanadium-Alloys' customers regularly make large purchases ("large" in the toolsteel trade) of rounds for 3/8-in. twist drills—almost a Sears-Roebuck item—yet no two of them specify the same diameter!

Some metallurgical items of interest were also uncovered during inspection of the London plant. Ingots of high speed toolsteel are small, 10 in. square on top; 9 in. on bottom, 20 in. high. They are cast on copper stools; taper-walled molds are thick at bottom, quite thin at top; thus solidification starts promptly at bottom, and is delayed at top. Shrinkage is fed by a rather unique refractory hot top, a 12-in. cube, placed on each mold immediately before pouring, and so hot it is almost plastic. The pouring gate in the center is conical, 4 in. diameter at bottom and 7 in. at top. An exothermic compound is placed on the molten metal immediately after the ingot is teemed, and remains so fluid that its top surface is flat at the end. This conical projection is easily broken off the ingot and the fracture tells the skilled melter a good deal about the quality of each ingot. Hot top discard also is less than 5%.

L. D. Bowman, , vice-president for operations, said that an advantage of hammers and presses ordinarily used in toolsteel mills rather

than blooming mills (other than their lower capital charges) is that the expert hammerman is able to observe any early tendency for corner cracks or top and bottom defects and take proper steps immediately to prevent their spread. Thus the yield of marketable metal is considerably higher if the ingots are forged rather than bloomed. There is more loss from scale in a hammer department, but this does not eat up the gains from the other factors. The hammer or press also breaks up and distributes carbide grain boundaries more effectively in the high-carbon steels when the amount of reduction from ingot to die block is moderate.

A New Steel for Pressure Vessels

Now-a-days it evidently is not enough for the boys in the metallurgical department to devise a heat treated, low-alloy steel, with excellent weldability without preheat or stress relief, good impact strength, ductility and bendability in all directions, low temperature of transition from ductile to brittle type of fracture, and various other qualifications and examinations numbering 77 in all – it is not enough to devise the steel, but convince the manufacturing department that it can be made and heat treated in existing equipment, and the sales department that it can be sold at the necessary price. After the U.S. Steel Corp.'s technical staff was able to do all this, the experience of the Chicago Bridge & Iron Co. with welded pressure vessels was enlisted and some cylinders were designed, constructed of the new alloy, and tested, to prove the hopes of the promoters. Finally, in a two-day program staged at Birmingham, Ala., for some 300 metals engineers from all over the United States, four tanks were tested to destruction while their death throes were recorded by batteries of movie cameras, thermocouples, and strain gages. Leon S. Bibber, welding research engineer who was responsible (he "headed task-force for Operation T-1", to adopt the official *cliche*) doubtless heaved a sigh of relief at the end, not that he had much doubt that the pressure vessels would perform nobly, but that some of the human or electronic observers might get into trouble, despite his best laid plans.

The less colorful metallurgical details can be listed as follows: The steel is dubbed "Carilloy T-1" – "U.S.S. Carilloy" being a trade name used by the Corporation for 15 years for the conventional and special alloy steels produced by the subsidiary then known as Carnegie-Illinois Steel Corp. In the Corporation's trade literature, the usual chromium-molybdenum analyses were recommended for pressure vessels operating at high temperatures, and 2315 (0.50 Mn, 3.50 Ni) for low temperatures. Much Grade B Firebox steel, plain carbon steel corresponding to A.S.T.M. specifications A 201 and A 212, has also been used in the past. The new "Carilloy T-1" resembles the triple-alloy steels developed during war time, but with other elements added for this or that (0.15 C, 1.00 Mn, 0.90 Ni, 0.50 Cr, 0.50 Mo, 0.35 Cu, 0.05 V, boron and aluminum treated), and is heat treated at the mill by water quenching from 1650° and long tempering at 1200° F. It has exceptional freedom from directional properties, a yield strength (load for 0.2% elongation) over 90,000 psi., good ductility, Charpy keyhole impact over 15 ft-lb. at 70° F., transition from ductile to brittle fracture below −150° F.

The four tanks tested were made of ½-in. plate, 4-ft. diameter, 20-ft. length, with ends of five spherical segments. Two tanks were stress-relieved, two not. All the Birmingham tests were made while the tanks were at −35 to −50° F. and full of refrigerated brine. Two were cracked by internal pressure at 2850 psi. pressure and nominal stresses of 135,000 psi. (somewhat above the ultimate strength of test pieces cut from the original plate). The other two were supported near the ends, pumped up to 1875-psi. internal pressure, and a saddle mid-length hit by a 13-ton ingot falling successively from 50, 75 and 100 ft. They cracked only after the last drop.

E. C. Wright, *Metal Progress's* consulting editor who was present, writes that "a striking feature of both the bursting and drop tests was that every bit of the fracture was of the ductile shear type, and there was no evidence whatever of brittle fracture" under the conditions of extreme cold, high multi-axial stress, and impact – conditions which Professor Shank says, in his article immediately following, have been associated with catastrophic failures with brittle fracture.

As to cost: At the mill it will be about 2½ times that of firebox steel. If the Codes can be revised to permit the designers to use one half the minimum yield stress of the new alloy steel ($0.5 \times 90{,}000$ or 45,000 psi.) as the tests indicate will be safe, instead of one quarter of the ultimate strength ($0.25 \times 70{,}000$ or 17,500 psi. now permissible for carbon steel) then the amount of steel, welding and other cost elements going into a given pressure vessel will be so much lower that notable savings can be demonstrated.

Fig. 1 — Fragment of a Fractured Drum. Note shiny, faceted appearance, sometimes called the chevron pattern. Apices of herringbone markings point to the origin of failure

Brittle Failure of Steel Structures —a Brief History

*By M. E. SHANK**

Although 250 welded ships have been disabled since 1940 by brittle cracking, such failures began as soon as steel plate became available for structural use and include storage tanks, bridges, booms and long pipe lines.

During World War II the problem of brittle failure received sudden prominence with the breaking up at sea and at dockside of welded steel merchant vessels, especially Liberty Ships and T-2 tankers. For this reason, in the minds of some persons, the problem of brittle failure is associated mainly with ships. However, a study of other steel plate structures shows that brittle failure is a general engineering problem, not confined to ships nor any other single category.

Neither is the problem a new one. In 1856, Bessemer announced his process of steelmaking, and shortly thereafter steel became available in comparatively large quantities. A few years later (1861), openhearth steel became available. Formerly, steel had been made by carburizing wrought iron; it was scarce and expensive; therefore, it was limited to such uses as cutlery and

*Assistant Professor of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

This paper is based, in part, on a report to the Committee on Ship Structural Design of the National Academy of Sciences, National Research Council. The Committee on Ship Structural Design is advisory to the interagency Ship Structure Committee which supported this investigation as part of its research program.

The complete report, "A Critical Survey of Brittle Failure in Carbon Plate Steel Structures Other Than Ships", was published as Report SSC-65 by the Ship Structure Committee, U. S. Coast Guard Headquarters, Washington 25, D. C. It is also available as Bulletin No. 17 of the Welding Research Council.

The opinions expressed in this article are those of the author and do not necessarily represent the views of the Committee on Ship Structural Design or the Ship Structure Committee.

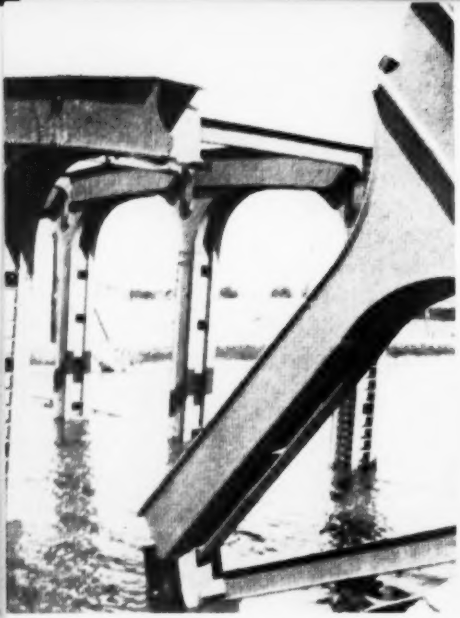


Fig. 2 – Hasselt Bridge in Belgium. Note extreme brittleness of breaks (Metal Progress, *May 1939, P. 492*)

Fig. 3 – T-2 Tanker Which Broke in Half at Dockside

springs. Wrought iron and cast iron were the structural materials. In Great Britain, Board of Trade regulations prohibited the use of steel in construction, and their revision in 1877 provided a great stimulus to the steel industry in that country. Thus, during the period of 1860 to 1890, both in Europe and the United States, wrought iron was gradually being supplanted as a structural metal by steel. Reluctance by engineers to discard the old reliable wrought iron caused the change to come about slowly, but in the long run, the cheapness, greater availability, and superior strength of steel won out. As more steel came into use, troubles with brittle failure began to appear.

In the *Journal* of the Iron and Steel Institute for 1879 appears a paper by Nathaniel Barnaby on "The Use of Steel in Naval Construction". Mr. Barnaby deplores: "Recent cases have occurred of fracture in bessemer bars . . . from some trifling blow or strain . . . they nearly all took place during the late severe weather at Chatham."

In the ensuing discussion of the paper, Mr. Barnaby was roundly denounced by the assemblage. However, in that same meeting one Mr. Kirk complains of the cracking of steel in a mysterious manner. In particular, he cites a steel plate which "when cold, on being thrown down, split right up. Pieces cut from each side of the split stood all the Admiralty tests. Now given a material capable of standing without breaking an extension of 20% he wanted to know . . . how a plate . . . could split with a very slight extension . . . not to the extent of 1%."

Mr. Kirk thereupon asked the steelmakers for a remedy to this problem, and, if a remedy was not available, at least a rational explanation. His question was totally ignored. Today the problem is yet with us, and modern engineers and metallurgists are still striving to satisfy Mr. Kirk's request of 75 years ago.

It might be well to summarize briefly the manifestations of brittle fracture occurring in carbon steel plate.

Three conditions may combine to bring about such failures: First is low temperature – say +40° F., to –40° F., such as exists in the ambient atmosphere. Second is the presence of a notch (introducing triaxial stress); any defect such as a welding crack or a void, or a crack left by a punching or shearing operation can serve as a notch which will initiate brittle failure, and so it is sometimes called "notch brittleness". The third factor is high strain rate, but such impact loading is not necessary for brittle failures; as will be shown, many have been initiated under what appear to be completely static conditions.

When brittle failure occurs, it may be recognized by several earmarks. Among these are the speed at which fracture occurs (approaching several thousand feet per second), almost complete lack of ductility, negligible energy absorption, and a "brittle" or faceted appearance of the

fractured surface. Moreover, the fractured surface often has a characteristic "chevron" or "herringbone" appearance, the apices of the herringbones pointing to the origin of the fracture, an extreme example of which is shown in Fig. 1. Finally, when steel plate taken from a structure which failed in a completely brittle manner is tested in an ordinary tension test, it manifests a high degree of ductility and strength! It is this last characteristic which was so baffling to engineers.

Failures of Riveted Structures

Steel plate was customarily joined by rivets, of course, up to about 30 years ago. The earliest structural brittle failure on record, apparently, is a riveted water standpipe at Gravesend, Long Island, in 1886. It was an ambitious design, 250 ft. high, 16 ft. in diameter up to a height of 59 ft., decreasing conically in a length of 25 ft. to an 8-ft. diameter, which was retained to the top. The whole was steadied by guy wires. Plates in two sizes, 5x7 ft., and 5x9 ft., were employed with thicknesses varying from 1 in. at the bottom to ¼ in. at the top. All joints were triple riveted. Failure occurred during the hydrostatic acceptance test. Water had been pumped to a height of 227 ft. when there was a sharp rending sound; a vertical crack appeared in the bottom, running up about 20 ft. The whole tower then collapsed. An eye-witness noted that the workmanship seemed to be good, that some of the upper plates were tough and ductile, having actually rolled up, while others in the bottom of the tower were brittle with glass-like fractures. He concluded that only a brittle material could have wrought the destruction that occurred, and that it seemed as if all this defective plate had been concentrated in the lower part of the tower.

From 1898 up through 1933 engineering publications contain occasional accounts of brittle failures of riveted water tanks, gas holders, oil storage tanks, and ships. However, since 1900 over a dozen riveted merchant ships have broken in two or are listed as missing. It may be significant that most of these vessels were of the tanker type (the same category that has given the most trouble in welded ships) but such famous passenger liners as the Leviathan and the Majestic experienced cracks in their upper strength decks. These cracks started in square openings and sometimes extended to the shell – some even extended down the shell. In at least one case a loud report accompanied the forma-

Fig. 4 – Failed Spherical Pressure Vessel at Morgantown, W. Va., Showing Long Brittle Tear

Fig. 5 – Failed Power Shovel Boom. The end of the boom (pressed plate) has broken off

tion of a crack, indicating brittle fracture. The Europa had similar cracks.

The most famous brittle failure of a riveted structure was a molasses tank in Boston. One January day in 1919, when the tank contained 2,300,000 gal. of molasses, it burst open. Twelve persons were drowned in molasses or died of injuries; 40 others were injured. Houses in the path of the flood were damaged and a portion of the Boston Elevated Railway knocked over. An extensive lawsuit followed, and many well-known engineers and scientists were called to testify. Much conflicting testimony was presented as to the cause, and it was here that the significance of the chevron pattern in a service failure (see Fig. 1) was recognized.

Finally after years of testimony, the court-appointed auditor decided that the tank failed by overstress. In comment he said: ". . . Amid this swirl of polemical scientific waters it is not strange that the auditor has at times felt that the only rock to which he could safely cling was the obvious fact that at least one-half of the scientists must be wrong. . . ". This statement fairly well summarized the engineering knowledge (or lack of it) concerning notch-brittle behavior.

Failures of Welded Structures

Bridges—Just prior to World War II, about 50 bridges of a type known as a Vierendeel truss were built across the Albert Canal in Belgium. They possessed straight lower chords and curved upper chords, joined by verticals. There were no diagonals, yet the structure was a very rigid one. Some of these bridges were built of welded or rolled I-beam and plate, others entirely of plate. The span and detail were varied to suit the location. In March 1938 when the weather was quite cold the bridge at Hasselt, with a span of 245 ft., collapsed into the canal (Fig. 2). Eyewitnesses heard a sound like a shot and saw a crack open in the lower chord. This left the top chord acting as an arch. Six minutes later the bridge broke into three pieces, and fell into the canal. All the fractures were brittle, some through welds, others in solid plate away from the welds. The bridge was lightly loaded at the time. Within two years, two similar bridges failed in the same way.

These failures set off a great flurry in engineering circles. Numerous references to them, and to the supposed cause, were made by foreign correspondents to *Metal Progress*. The Belgium-Luxembourg steel industry claimed that the quality of the steel was above reproach, and the failure of the Hasselt bridge was due to poor welds. Representatives of the welding industry had also visited the site and satisfied themselves that the failure was not due to the weakness or imperfection of the welded joints.

Both judgments were premature. Several years later a thorough investigation was undertaken by two Germans, H. Busch and W. Reuleke. They reported that most failures were initiated at welds, and that many welds were defective. They found that on Charpy notch-impact tests practically all specimens were brittle (at least in part) at the cold temperature which existed at the time of failure. Their conclusions stated that the accident was caused by *(a)* multiaxial restraint and residual stress, *(b)* low ambient temperature, *(c)* low notch-impact characteristics of the steel. They seriously questioned whether nonkilled bessemer steel should be used in thick plate, despite good static-tension properties, since its notch-impact is low.

The Vierendeel bridge failures were a prelude to the brittle ship failures which occurred in World War II. Between 1942 and 1952 about 250 welded ships suffered one or more brittle fractures of such severity that the vessels were lost or were in a dangerous condition. Nineteen of these 250 ships broke completely in two or were abandoned after their backs were broken; 11 were tankers, 7 were Liberty Ships for dry cargo. In the same 10-year period, 1200 welded ships suffered brittle cracks, generally less than 10 ft. in length, which did not disable the ships but were potentially dangerous. The foregoing figures are for ships over 350 ft. long; very few failures have occurred in smaller vessels.

Ships—The first welded ship failure was that of a T-2 tanker in January 1943. While the vessel was sitting quietly at her fitting-out pier in Portland, Ore., the deck and sides fractured amidship with a report heard for at least a mile. The vessel, held together only by its bottom plating, jack-knifed so the center rose out of the water. See Fig. 3.

In Liberty Ships, the majority of the failures started at square hatch corners and square cutouts in the top of the "sheer strake"—that is, the highest strip of shell plating. The frequency of serious failures was reduced after structural details, such as hatch corners, were redesigned. In addition, riveted straps or crack arresters—similar to butt straps in riveted plate work—were installed in the deck and at the gunwales, and all plate welds terminated in a slot behind these crack arresters.

In the T-2 tankers, most failures initiated in defects at butt welds in the hull. No simple remedial measures were possible, but finally four or more crack arresters were installed on these tankers, two on the deck and two in the bottom. It is to be noted, however, that crack arresters, while limiting the *extent* of cracks, do not *prevent* their occurrence, and so the frequency of serious fractures in T-2 tankers did not markedly diminish. A recent directive of the American Bureau of Shipping calls for installation of additional crack arresters in these ships, as well as strengthening the hull girder.

Pressure Vessels—Brittle failures of pressure vessels have occurred in recent years. One of these occurred in Schenectady, N. Y., in February 1943. The vessel was a spherical hydrogen tank of welded construction, 38.5 ft. in diameter, with 0.66-in. wall of semikilled plate. It had been in service three months. The design was in accordance with Paragraph U-69 of the A.S.M.E. Code for Unfired Pressure Vessels. The design called for a working pressure of 50 psi., a working stress of 11,000 psi., and a weld efficiency of 80%. In 1942 it had been tested at 62.5 psi. and showed no leaks. The manhole of the tank had been made in two subassemblies (bolt flange of neck in one, collar and sphere plate in the other) and had been field welded in place. All manhole plates were made of ⅝-in. sheared cold rolled plate. The plates were dished cold, and in accordance with Paragraph U-69 of the code, not stress-relieved.

On the day of the fracture the ambient temperature had been below zero, had risen 27° F. in 7 hr., and was 10° F. when failure occurred. The internal pressure was about 50 psi. The sphere burst catastrophically into 20 fragments, with a total of 650 ft. of herringboned brittle tears. The tears were plotted on a model, with directions of herringbones marked by arrows. All herringbones led back to the manhole, which was the origin of fracture. The intensity of the failure was greatest in the manhole region.

The general quality of the welding was excellent. Only a few feet of fracture followed welded seams or the heat-affected zones alongside. Later examination of the relief valves showed them to be operating satisfactorily. Except in a minor way, fractures did not involve support-leg attachments where stresses were high. On good evidence the possibility of internal explosion was eliminated. The field assembly of the manhole neck required heavy welds of many passes, and old cracks were found, as well as many small cracks in the inner, sheared edge of the neck.

Fig. 6 — Failed Gas Line, 30 In. Diameter, Showing Sinusoidal Nature of Fracture. Note longitudinal welded seam, which appears to be intact. Presumably this failure occurred while installation was being tested. (Courtesy Lincoln Electric Co.)

The investigators believed the causes to be:

1. High stresses at the manhole neck resulting from the presence of the hole in the sphere.

2. Residual stresses approaching the yield point in the manhole neck due to shrinkage of the heavy welds; there were several old radial cracks in this region.

3. The use of semikilled steel, which was brittle under the existing circumstances.

4. Probably thermal "shock" due to the rapid rise of temperature which increased the hydrogen pressure, or to thermal stress resulting from uneven heating by the sun's rays. The large amount of energy available from the compressed gas was sufficient to scatter the pieces without an explosion.

The investigators recommended that gas vessels should be tested at twice the working pressure with water, rather than 1¼ times the working pressure with gas, and that subassemblies (such as manholes and nozzles) should be built in the shop, stress-relieved, and Magnafluxed for cracks, and designed to avoid heavy, built-up weld deposits which cause high residual stress.

Other spherical pressure-vessel failures occurred in Pennsylvania in March 1943 during a test, and at Morgantown, W. Va. (Fig. 4) in January 1944, also on test. In Cleveland, extremely disastrous failures occurred in a cylindrical and in a spherical gas pressure vessel in October 1944. These two vessels, built of a 3½% nickel steel, had been used to store liquefied

natural gas at a pressure of 5 psi. gage and −260° F. Burning liquid got into the storm sewers and fire spread into several blocks of residences nearby. In the ensuing holocaust 128 persons were killed, and damage amounting to $6,800,000 resulted.*

Other Structures – Failure of power-shovel booms and dipper sticks (the member which carries the bucket) have been reported. Most of these occurred in cold weather, at −15 to −20° F. Figure 5 shows a power shovel on which the end of the boom has broken off. The material was a "Man-Ten" plate, containing 1.25 to 1.70% manganese, usually classified as a low-alloy steel.

Similarly, the brittle failures of oil-storage tanks, a smokestack, and a penstock have been reported. Three new oil-storage tanks broke up before they had ever been filled. The weld overfill on the seams inside the tank had been chipped flush during erection, leaving tiny notches. Following a sharp temperature drop, long cracks appeared across the welds, entering the plates on either side.

Pipe Lines – In the period since 1948 failures have occurred in high-pressure gas transmission pipe lines. Pipe for these cross-country lines is now usually produced according to an American Petroleum Institute standard, which specifies grades of strengths. Comparatively high values of carbon (0.34% max.) and manganese (1.30% max.) are allowed. In one method of manufacture the pipe is cold formed, seam-welded, and hydrostatically cold expanded, both to round it and to boost its yield strength up to the value specified. It is then hydrostatically tested. Raising of the yield by cold work has an important economic consequence. Inasmuch as a thinner pipe wall can thus be used, a considerable weight of steel can be eliminated. Large savings result.

Installation methods and allowable pressure in transmission lines are covered by an American Standards Association code (now being revised). Under this code it is permissible, in sparsely populated areas, to carry a pressure (approximately 800 psi.) which will stress the pipe to 72% of its yield strength. In more densely populated areas stresses from pressure are limited to about 50% of yield strength.

There is little published information concerning failures in gas-transmission-lines. One short article says they range from 180 to 3200 ft. in length. (The failures here described occurred on test, after installation.) The cause – presumably the initiating cause – is stated to be well known, namely, gouging or scratching of the plate in transit or installation. The failures always follow a sine wave pattern and look as though there had been an internal explosion. See Fig. 6.

In addition, a report of the Federal Power Commission lists a number of "splits" of pipe which occurred on test and in service. These splits were in the pipe itself, not in the weld. Details about these accidents are unobtainable – indeed, many of the data were probably lost in subsequent repair and replacement. It seems probable that some of these splits represented brittle breaks, but that others did not.

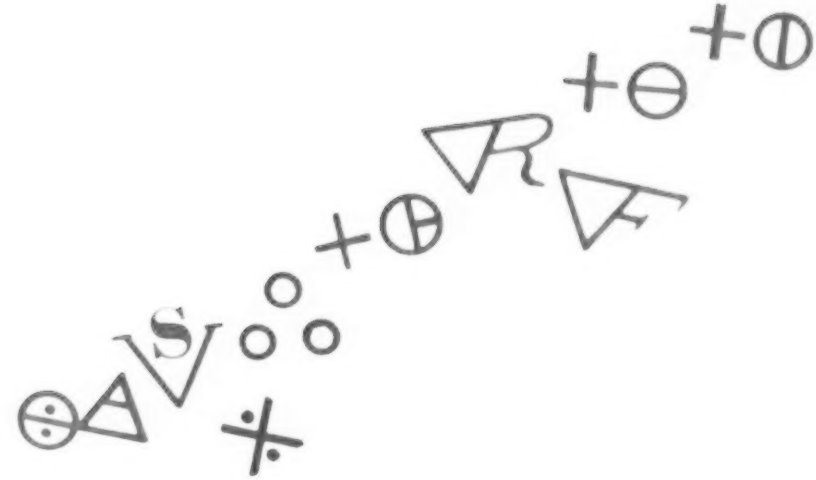
Because detailed technical information is lacking, definite statements about brittle pipe-line failures are difficult. However, some interesting speculations can be ventured. One speculation concerns field welding to join sections of pipe. With the upper limits of carbon and manganese contents allowed in the steel under A.P.I. Standard 5LX, trouble may be encountered in field welding of girth joints, since air hardening and subsequent cracking might occur in the heat-affected zone.

Another speculation concerns the rate of crack propagation in steel versus the rate of pressure released in natural gas (methane) following a pipe break. The gas pressure will be released by an elastic wave traveling at the speed of sound, approximately 1300 ft. per sec., and this rate will not be affected by pressure. Experimental values of 2750 to 6600 ft. per sec. have been measured in brittle fracture of steel in the laboratory. Thus it appears that the gas-discharge pressure wave will never catch up with the brittle crack; the tip of the crack is always traveling in a stressed area. This would account for the long breaks described. Testing of pipe lines with water might prevent such long breaks, inasmuch as the velocity of an elastic wave in water is about 4800 ft. per sec.

To determine this and other unknown factors the gas industry is sponsoring a considerable amount of research on the complex problem of brittle failure.

*This disaster was extensively studied, and the report of the Mayor's Commission is on file in the Cleveland Public Library. Reports of investigations sponsored by the East Ohio Gas Co. and by the U.S. Bureau of Mines are also available on request.

Editor's Footnote – This brief article about the history of brittle fractures in notable structures will be followed by others discussing the factors of importance in such failures, the probable mechanisms of crack propagation, and the possible solutions.



Metallurgy in the Days of Alchemy

By CARL ANDREW ZAPFFE*

In "Light Metallurgy" in last November's issue, R. P. Lister suggested that alchemical gibberish was due to contrasting urges – the scientist's urge to publish and the industrialist's urge to secrecy. Carl Zapffe now shows that alchemical symbols were in common use in 1776, and some of the "principles" were not so erroneous. For example, change "phlogiston" to "energy" and that theory makes sense to physical chemists.

DURING the reign of Ptolmey Philadelphus in Egypt (285 to 247 B.C.), the Pharos of Alexandria was built by Sostratus of Cnidus. This was the father of lighthouses and one of the Seven Wonders of the World. Built of white marble blocks bonded with cast lead, it stood aproximately 600 ft. high and contained some 300 rooms. An immense mirror capped the structure, mounted upon trunnions such that it could be turned to focus the sun's rays upon enemy ships – allegedly being able to set them on fire at distances up to 100 miles.

According to later Arab tradition, this Pharos was built upon a foundation of glass, and the means of its selection strikes a familiar note for the modern student of corrosion familiar with Kure Beach in North Carolina, the extensive marine corrosion station. Thus, Sostratus immersed "stone, brick, granite, gold, silver, copper,

*Metallurgist, Baltimore, Md.

lead, iron, glass, and all kinds of minerals in the sea to test them. When they were taken out and examined the glass alone was found full of weight and unimpaired."

So glass was chosen—in great blocks!

Organization of Alchemy – Such descriptions of ancient works and monuments* are useful in reminding one that ingenuity and intellect have long been attributes of the human race. Modern science is primarily the product of a state of organized thought, rather than a special acquisition from mental powers lacking in our predecessors, and metaphysics and alchemy represent its prior or preliminary stages.

In turn, their origins are as old as recorded history, first taking outline as an occult cosmology within a web of religion by the almost legendary figure of Hermes Trismegistus in ancient Egypt. Then in the 4th Century B. C. Aristotle founded a logic for physics and metaphysics simultaneously, established the Peripatetic School in Greece, and laid the headstone for occidental intellectualism. It was Aristotle's special ward, Alexander of Macedon, who in the brief span of 13 years, and before he was 33 years of age, spread Aristotelian philosophy across the lands he conquered from Libya in Africa to the Hindu Kush, and who built the city of Alexandria in Egypt where the Pharos was erected half a century later. The entire status of civilization became altered, largely pivoting thereafter upon the libraries and schools of Alexandria.

When this center of world learning was destroyed in the declining years of the Roman Empire, Arabian scientists and philosophers such as Geber and Avicenna kept the intellectual light burning until Copernicus, Galileo, Newton, and their contemporaries completed the bridge to modern science. The writings of Copernicus remained laden with astrology and metaphysics; and as recently as the time of our own Revolutionary War, as will shortly be described in detail, chemistry and metallurgy were still being described in terms of alchemical symbols.

Strictly speaking, alchemy itself is but a structural unit standing within this broad historical edifice. It was not until several centuries of the Christian Era had elapsed that transmutation—the identifying element of alchemy—appeared on the scene, and not till after the first millennium was there much in the written record. While this is no place to enter into the involved and continuing discussions on alchemical interpretation, we should recognize the impact of Christian philosophy upon the two streams of physical and metaphysical thought mentioned above. Influenced by the religious concept of Christ's resurrection, both physical and metaphysical thought acquired hypotheses about transmutation from lower to higher forms, from impure to pure. For the metaphysical branch, discussions remained esoteric and confined to spiritual processes taking place within man; in the physical branch (probably for the very reason of the ancient entwinement of science and religion) the students pursued an esoteric but parallel course which attempted to force upon the natural elements those transmutations symbolized in spiritual discussions by lead, silver, gold, and so forth. Whether transmutation was ever acomplished physically remains a matter of warm dispute. That physical transmutation is an inherent possibility of the natural order is now ***mirabile dictu*** an established fact. The only feature of present concern, however, is that this physical branch—alchemy—is the one that eventually spawned the scientific era, and the latter sharply separated itself from the metaphysical stream and from the entire parent element of religion.

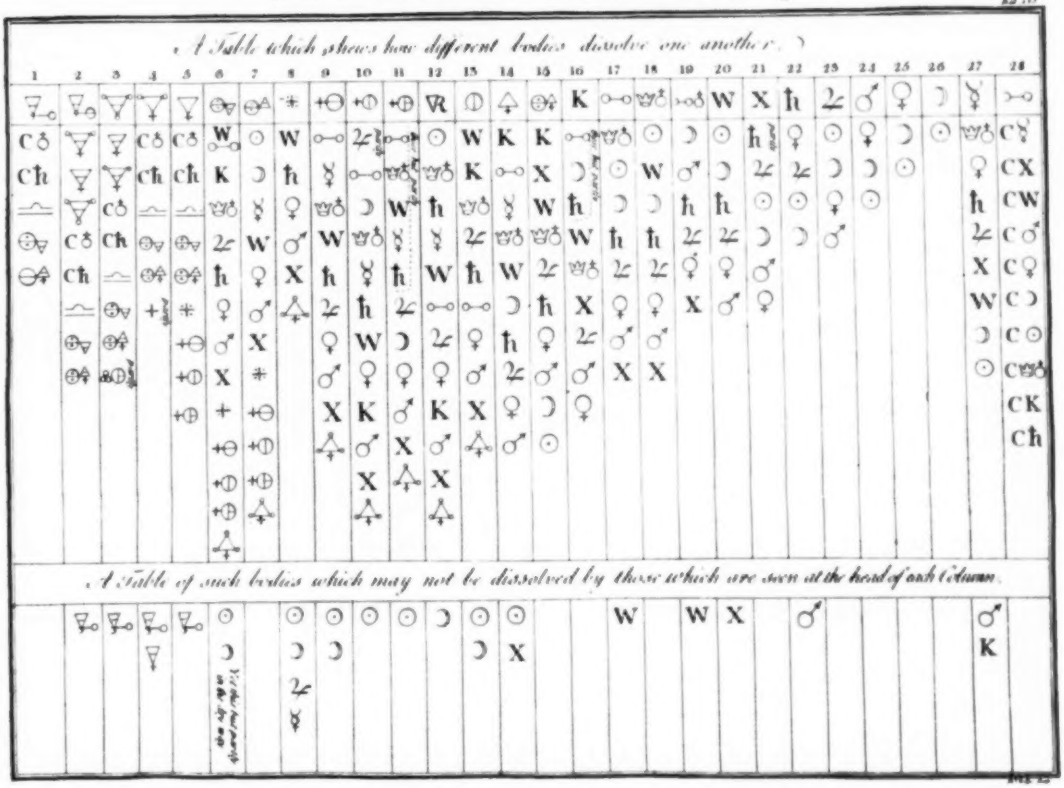
The General Alchemical Concept

In order to extract some information from the accompanying tabulations, some principal features of the alchemical viewpoint must first be outlined. Primary consideration was usually given to the *principle*, or the essential quality of a body or a phenomenon, rather than to its physical measurements – that is to say, to solidity and liquidity rather than to solids and liquids. Thus, the three states of matter (or their *principles*) as we know them today were designated earth, water, and air in the Aristotelian system, with fire added as a fourth fundamental attribute to explain the mysteries of light, heat, and combustion. It is typical of the profundity of Aristotle that his fourth state of matter, designated "fire" – historically associated with transmutation, and definitely not to be restricted to chemical flame – retains a peculiar applicability for the field of nuclear physics. Perhaps we now would use the term "energy" to denote the concept.

In subclassifying the solid state, three kingdoms were recognized much as at present –

*The information and quotation is from "Wonders of the Past" (Vol. 2, p. 419), published in 1924 by G. P. Putman & Sons, New York City.

Table I–Chemical Table of the Alchemists as Given by C. E. Gellert in 1776. See Table II for decoding



(*a*) mineral, (*b*) vegetable, and (*c*) animal. The minerals were interchangeably called "fossils", equally to the confusion of the ancient student and the modern historian. A 1671 text, "Metallographia: Or a History of Metals", by J. Webster, provided a typical example of that confusion by devoting an entire chapter to a discussion of whether metals ". . . grow, and have vegetability, or not". The genius of Leonardo da Vinci pierced the veil surrounding what we now call fossils; nevertheless, 400 more years elapsed before their identity as organic remains was accepted, since a fossil automatically raises the same issue with the Biblical account of creation that Darwin's work encountered.

Metals – By the 18th century, C. E. Gellert (whose book will be described a little later) recognized eight classes of chemicals and materials: (1) earths; (2) stones; (3) salts; (4) sulphur; (5) metals; (6) semimetals; (7) ores, and (8) mineral waters. He listed six metals: gold, silver, copper, lead, tin and iron, to which mercury could be added as a seventh. Metals in ancient thought have always been seven in number, specific in esoteric significance, and closely related to such exoteric things as the planets and the days of the week:

Sunday	Gold	Sun
Monday	Silver	Moon
Tuesday	Iron	Mars
Wednesday	Mercury	Mercury
Thursday	Tin	Jupiter
Friday	Copper	Venus
Saturday	Lead	Saturn

Derivations for Sunday, Monday, and Saturday are obvious; but Tuesday similarly develops from the Anglo-Saxon *Tiw*, equivalent of Mars; Wednesday from the Saxon *Woden* and Scandinavian *Odin*, counterpart of the Roman Mercury; Thursday from the Scandinavian *Thor*, an equivalent of the Roman *Jove* (genitive term for *Jupiter;* witness the French *jeudi* for Thursday); finally Friday from the Norse *Frigg* who, as wife of Odin and goddess of the sky, corresponds to

Venus. These explanations help recover at least a fragment of an original logic in the above listings.

Thoughtless comment frequently deprecates these heritages because of an apparent nonconformity with our externalized science of today. However, those ancients who were first authorities in their field did not necessarily maintain that there were only seven elements to be classed as metals, nor only seven solar satellites. Their perspective was far removed from that of modern science, and often on levels of inquiry which at present are of only peripheral concern to science. Possibly some or even many of their discoveries may yet prove correct for the particular ontology they concern.

As for the semimetals, Gellert lists five: zinc, bismuth, antimony, arsenic, cobalt. His "antimony", however, refers to the sulphide ore,

Table II – A Decipher for Alchemical Symbology

	THE FOUR ELEMENTALS		
PHLOGISTON[a]	△ FIRE (energy)	AIR (gas)	▽ WATER (liquid)
	EARTH (solid)		
METALS[b]	**SEMI – METALS[c]**	**MINERALS**	
☉ GOLD	ANTIMONY[d]	VITRESCENT (hard refractories)	GLASS
☽ SILVER	REGULUS OF ANTIMONY[d]	FUSIBLE VITR. (flints, silicates)	ANTIMONY GLASS (Sb oxide)
♀ COPPER	W BISMUTH	ARGILLACEOUS (clay, talc, mica)[f]	LEAD GLASS (litharge)
♂ IRON	X ZINC	GYPSEOUS (plaster, gypsum)	33 CINNABAR (Hg sulfide)
♄ LEAD	ARSENIC	CALCAREOUS (limestone)	CINNABAR (Hg sulfide)
♃ TIN	K COBALT[e]	C CALX (slag)	ORPIMENT (As sulfide)
☿ MERCURY	Sublimed Hg / Precipitated Hg	SAND	ORPIMENT (As sulfide)
ACIDS	**BASES**	**SALTS**	**OTHERS**
+ ACID, in general	FIXED ALKALINE SALT[g]	COMMON SALT (NaCl)	SULPHUR
VEGETABLE ACIDS	VOLATILE ALKALINE SALT[g]	SAL AMMONIAC[h] (NH_4Cl)	HEPAR SULPHURIS (K sulphide)
DISTILLED VINEGAR	ALKALINE SPIRIT (ammonia)	SALTPETER (K,Na,Ca nitrates)	SPIRIT (vapor, fume)
HCl	QUICKLIME	VITRIOL (metal sulphates)	S SPIRIT OF WINE (ethyl alcohol)
HNO_3	POTASH	ALUM (double sulphates)	RECTIFIED SPIRIT (>95% alcohol)
AQUA FORTIS (conc. HNO_3)	H_2SO_4	VERDIGRIS (Cu acetate, carb.)	INFLAMMABLE SPIRIT
AQUA REGIA (HNO_3 – HCl)	OIL OF VITRIOL (66° Bé. H_2SO_4)	BORAX (Na borate)	INFLAMMABLE FETID OIL
POWDER	URIN	SOAP	OIL

whereas his "regulus of antimony" is the metal. The identification of cobalt is also open to question. Gellert's criterion is the beautiful blue color imparted to glass by "cobalt", and this seems secure, but other remarks indicate that a mineral is meant rather than cobalt metal. Here a passage from Gellert is interesting because nickel was discovered at about the time he was writing.*

> **Copper-nickel** contains sometimes a good deal of copper, but this ore being commonly mixed with cobalt, the unmetallic earth of which renders its working very difficult and unprofitable, it is mostly placed among the arsenical ores. This is probably the ore of which Cronstedt makes a new semimetal, called nickel, which is nothing but a mixture of iron, arsenic, cobalt, and a little copper.

This use of "copper-nickel" is an ill-advised literal translation of the German "kupfernickel", used for the copper-colored mineral niccolite, an arsenide of nickel.

In closing these brief remarks on alchemical definitions of metals, semimetals, and minerals, the following two excerpts will not only lighten the burden of the review, but will call forth some useful reflections on the homely beginnings of our culture:

> **Goose silver ore** (so-called from its exact likeness with the goose dung) is a marle-like, pale and brownish, very rich glebe, and often surrounded and interwoven with filaments of native silver. The same name is given to another sort of a greenish gray silver mineral, having nearly the same colour of that goose dung.

> In collecting or purchasing of ores, care must be taken to prevent imposition: For, there are some ingenious fellows who know how both to compose artificial ores, and to join natural pieces so artfully together, that the cheat may not easily be discovered with the eye; and from whence many theoretical and practical errors may arise. Oftentimes this cheat may be detected by putting such mineral stones into hot water, or in brandy, for, if they are joined with gum or resinous substances, one or the other will make them fall in pieces.

Chemicals – By the term *dissolvent menstrua*, the alchemist referred to his solvents and corrosive agents. These were broadly divided between (*a*) "dry", exemplified by mercury, but including other substances leading to fusion by fire, and (*b*) "liquid", principally comprising aqueous solutions.

At certain stages of alchemical development, the term "salt" was used to signify the principle of solidity, in a triad of primary concepts including mercury for the principle of liquidity and sulphur for the principle of combustion. By Gellert's time "salts" were the acid, alkaline, or neutral residues of evaporated metalliferous acids (also called "vitriols", and sometimes "sugars"). Three naturally occurring vitriols were recognized: blue vitriol (copper), green vitriol (antimony), and white vitriol (zinc).

Considering the fact that analytical tools of precision are entirely a recent development, this pre-science did remarkably well in analyzing most of the simple inorganic salts. More complex

*Nickel was first isolated by Cronstedt in 1751 and obtained in a pure state by Bergmann in 1775.

Footnotes to Table II on Opposite Page

(a) The principle of light, heat and combustion – or the essence of the Fire elemental – was termed "sulphur" by early alchemists, and "phlogiston" by J. J. Becher and his student G. E. Stahl in the late 17th century. Lavoisier's discoveries with oxygen broke that chain of thought and gave origin to thermodynamics, which in turn is perhaps now to give way to nuclear physics as the inheritor of the ancient metaphysical concept.

(b) Alchemical metals are characteristically these seven, though Gellert omits Hg. Their order of listing is constant for the Au-Ag-Cu triad, but variable for the others, although originally the geocentric Ptolemaic theory gave them order according to the supposed distance from the earth of the planet to which the metal referred.

(c) This listing of "semimetals", taken from Gellert, represents a late stage of alchemy. Although Sb may date back to very early times, Bi and Zn belong to the current millenium; and metallic Co was first isolated from the mineral and identified during the very period in which Gellert wrote. See also note (e).

(d) "Regulus of antimony" is the alchemical term for Sb, "antimony" referring instead to the sulphide ore *stibnite*.

(e) "Cobalt" undoubtedly refers to a metallic-looking mineral, probably the sulpharsenide *cobaltite*, analogous to the alchemical usage of "antimony" noted just above. The metal Co was isolated in 1742 by Brandt in Sweden and confirmed by Bergmann in 1790, this period also embracing the publication date of Gellert's book.

(f) These particular examples taken from Gellert indicate the measure of the abyss existing between alchemical and technical petrography.

(g) "Alkaline salts" were variously prepared from minerals and vegetables to produce sodas and potashes. Gellert even gives a recipe based upon boiled bullock's blood which "foams much up" and emits a "foetid smoke". "Fixed alkaline salts" were accordingly the sodium and potassium carbonates and hydroxides, while the "volatile alkaline salts" were the ammonia compounds.

(h) This name descends from ancient Egyptian times when the salt was prepared from the soot of camels' dung burned in the great Temple of Jupiter Ammon.

chemicals received definitions which became more ambiguous and more metaphysical with increasing complexity of composition; witness the following: "Tarter is a neutral salt, consisting of the vegetable acid, an inflammable earth, and an ardent spirit".

Combustion – Just two centuries ago, C. E. Gellert published in Germany the book to which reference has already been made. An outstanding example of Teutonic thoroughness, the text was translated into English and presented to the Royal Society in 1766, finally being published as "Metallurgic Chymistry" in the year of our Declaration of Independence. Gellert was a student of the works of Henckel, Becher, and Stahl, these last two being the inventor and the outstanding exponent, respectively, of the phlogiston theory of combustion – probably the last great fragment of alchemy to be blasted away by the increasingly exact tools and methods of the new scientific era.

The phlogiston theory was an attempt to solve the great problem of heat and combustion. As Gellert defines it in Seiferth's translation: "Every substance what is inflammable is in Chymistry called by the general name of ***Sulphur***, or ***Phlogiston***." Phlogiston was not regarded to be the thing itself, but rather a subtle substance or attribute which was able to pass in and out of the material.

Lavoisier laid the theory to permanent rest very shortly after Gellert's book was written, by his discoveries of the role of oxygen in combustion – a very special type of chemical reaction. Today, the advanced student of physical chemistry, in an attempt to discover why, and how far and at what speed a certain reaction may occur, marshalls thermodynamics, wave mechanics, statistical analysis, and the calculus of variations to his aid – possibly without getting much closer to the fundamental cause than did Becher and Stahl with their limited facilities.

The Alchemical Table

In the appended Table I there are 28 columns of alchemical symbols as given by Gellert. Table II provides a key to these symbols, also largely taken by the present author from the same source. Variations in the symbols are the result of the lattitude of expression they allow. For example, headings for columns No. 4 and 5 in Table I show no crossbar within the triangle because they refer to *molten* gypseous and calcareous minerals, respectively, whereas the symbol in the decipher (Table II) refers to the ordinary solid material.

At the top of each column in Table I is the signature or sign of that body or substance by which those beneath may be dissolved. Furthermore, the order from top to bottom is in the direction of increasing solubility ". . . because, by that means, in some columns, the order how they precipitate one another will then appear in the same time." For example, in the 14th column, sulphur dissolves "cobalt" (an arsenious sulphide) and arsenic with maximum difficulty, then mercury, antimony, bismuth, silver, lead, tin, copper in that order, with iron easiest of all. The second division at the bottom of the tabulation lists those materials which are completely insoluble within that particular column head (gold and zinc).

To aid interpretation of Table I, the column heads are decoded in Table III:

Table III – Code for Table I

Column Head	Substance
1	Hard refractories
2	Fusible refractories
3	Argillaceous earth or clay
4	Gypsum or plaster
5	Limestone
6	Fixed alkaline salt
7	Volatile alkaline salt
8	Distilled vinegar
9	HCl
10	HNO_3
11	H_2SO_4
12	Aqua Regia
13	Saltpeter
14	Sulphur
15	Impure potassium sulphide
16	"Cobalt"
17	Arsenic
18	Antimony
19	Sb_2O_3
20	Bismuth
21	Zinc
22	Lead
23	Tin
24	Iron
25	Copper
26	Silver
27	Mercury
28	"Glass"

Columns No. 1 to 15 and 28 are primarily of interest to the process metallurgist, and No. 20 to 27 to the physical metallurgist. Interest in chemistry and corrosion attaches to columns numbered from 6 to 19.

Corrosion–Beginning with the strong acids, *the spirit of common salt* +⊖ (hydrochloric

acid) is stated to dissolve iron, copper, lead and tin – the latter ". . . with violence and great noise". It slightly attacks mercury, but silver and gold not at all. When united with *spirit of nitre* +Φ (HNO_3) ". . . in a due proportion it is called *aqua-regia* ∇R so named from being the only acid which dissolves the king of metals, gold." *Aqua fortis* ∇F, as the aqueous solution of *spirit of nitre* +Φ, was stated to dissolve most metals and semi-metals, tin only slightly, and gold not at all – hence its use in "parting" gold from other metals.

As for *acid of vitriol* +⊕ (H_2SO_4), this was found to dissolve iron, zinc, copper, bismuth, arsenic, silver, and "cobalt". It was found especially reactive with iron and zinc when diluted with 20 to 30 parts of water, thereupon emitting ". . . vapors of a garlic-like smell which are highly inflammable". Only hot and concentrated solutions of acid of vitriol were found to attack copper and silver.

Among the weaker reagents, *oil* ∴ and *spirit of wine* ∇S were found to attack copper and brass to some extent, which is an interesting observation with regard to our modern distilling industry. *Acid salts of vegetables* +, such as vinegar, were found to dissolve copper, lead and zinc, but not gold, silver or mercury. Copper was attacked by *oil of tarter per deliquium;* and the volatile alkaline salt ⊕△ (ammonia) was found to dissolve copper, zinc, bismuth, sulphur, mercury, silver – also gold to a slight extent.

Alloying for Corrosion Resistance – In the following excerpt from Gellert, one sees the germinative stages of the present tremendous field of alloy metallurgy:

> It is remarkable that not only these acid salts, but even metals will dissolve easier and sooner, when by themselves, than when united and mixed together. From hence depends the principle of etching with wood-vinegar, or with tartar and salt in the brass-works; and likewise the utility of brass pump-pipes in such mines where the waters are of a corrosive quality. For the same reason brass indures the air better than copper.

He goes on to list experiences with alloying which are of interest to a student of the history of this field. The adding of tin to copper to produce "hard metal for bells and guns . . ." was, of course, about as ancient for Gellert as it is for us, since this defined the Bronze Age; and the combining of zinc and copper to form brass stretches back toward the beginnings of the Roman Empire (although the use of metallic zinc for such purposes, instead of zinc ore, came far later). Gellert's statement that lead dissolves in most metals except iron is pertinent to the modern use of leaded free-machining steels; and the discussion of embrittlement of metals by sulphur, arsenic and tin ties in directly with modern problems, still often costly, concerning hot short and cold short behavior during working.

Precursor of Galvanics and Thermodynamics – In these several concluding excerpts, germinative stages of both electrodynamics and thermodynamics appear:

> . . . copper is obtained from those vitriolic waters by means of iron, which being put in and left there for some time, precipitates all the copper in its native form. For, the vitriolic acid having greater affinity with iron than with copper, instantly seizes upon that, dissolves it, and lets the copper fall down in its metallic form, which collecting in the same place, which the iron compasses, takes exactly the same figure as the piece of iron had when immersed. This phenomenon has caused the ignorant to believe, that iron has been transmuted into copper.

Expanding upon the features of galvanic plating, Gellert points out that silver

> . . . will precipitate by throwing copper in the solution, copper with adding iron, iron with zinc, zinc with adding an alcaline-earth, and the alcaline-earth will precipitate with alcaline salt.

Today the Electromotive Table and measurements for $\Delta F = -nFE$ exactly define these phenomena formerly generalized by the alchemist. Relationships expressed today in terms of $\Delta F = -RT \cdot \ln K$ were also then in dim outline:

> If therefore anyone of these mentioned bodies is united with sulphur, it may be divested of its sulphur by one of these bodies which stand under it in the same column [of the table].

Gellert pointed out that this does not always occur exactly as designated, for two reasons: (*a*) The difference between the two reactions is insignificant, and (*b*) the reactants may themselves dissolve one another. For example, he points out, iron and copper in column No. 24 dissolve with greater difficulty than Fe-Ag or Fe-Au; hence copper cannot be "parted" from iron by using gold or silver because these dissolve in iron themselves.

(Addendum by 20th century metallurgist: While Gellert's point is acceptable, his choice of an example is unfortunate. Silver has a scarcely measurable solubility even in liquid iron, whereas copper has an appreciable solubility in the liquid and gamma phases, and gold is completely miscible in the liquid, with a solubility near 10% in the gamma phase.)

Book Review...

Jet Engines

Reviewed by E. E. THUM

JET, THE STORY OF A PIONEER, by Sir Frank Whittle. 320 p. Frederich Muller, Ltd., London, 1953. 16s.

DEVELOPMENT OF AIRCRAFT ENGINES AND FUELS, by Robert Schlaifer (engines) and S. D. Heron (fuels). 750 p. Harvard University Business School, Boston 63, Mass., 1950. $5.75.

THE FIRST of these books is almost exclusively devoted to Whittle's homeric struggle to develop jet propulsion for fighting aircraft, and is a human rather than an engineering document. Although he was the pioneering inventor, his was not the only intensive work on gas turbines in the 1940's, even in his own country, as might be surmised if only his own story is read. The book by Professor Schlaifer gives the international picture, and a far more complete one for the aeronautical, mechanical and metallurgical engineer.

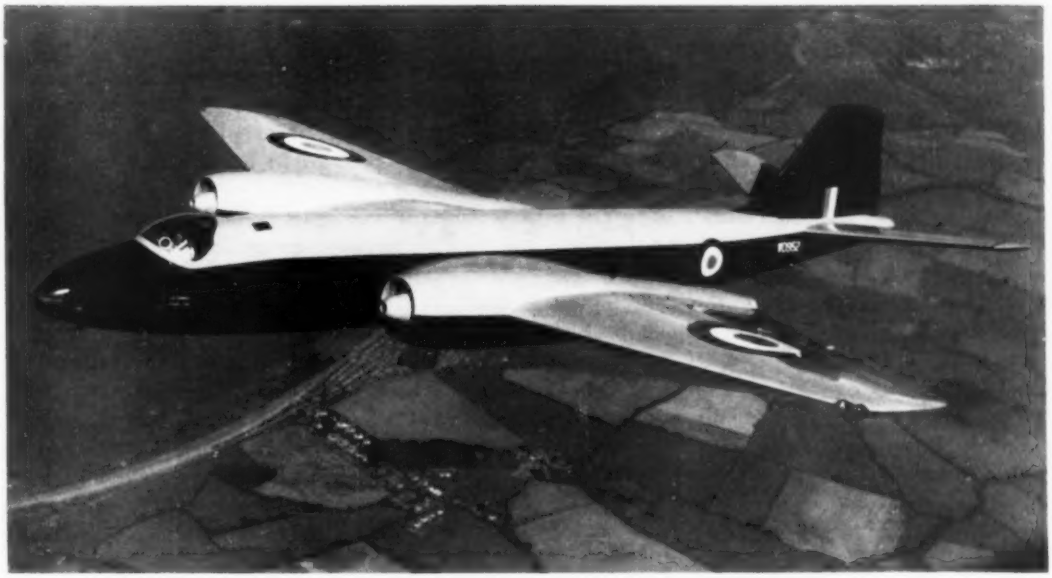
Whittle was born in 1907, the son of a hard-working "small business man" in the true sense of the term. When 10 years old he operated a lathe on spare time in his father's shop, making piston rings. A very poor student by schoolteacher's criteria, he enlisted as aircraft apprentice when 16 years old and in three years became an expert rigger for metal aircraft – advanced designs for those days. This training served excellently in later years, for his early engines were largely sheet metal casings, ducts, vanes, burners, diffusers and tail pipe surrounding a forged shaft carrying turbine wheel and cast impeller.

As a flight cadet he wrote a paper on "Future Developments in Aircraft Design" wherein he was thinking of speeds of 500 miles per hr. at very high altitudes – truly advanced when it is remembered that the fastest British fighter could then make 150! Not until 1929 when training as a flying instructor, did he hit upon an engine for such a craft – a gas turbine thrusting the ship forward rather than a propeller pulling it.*

No encouragement was given the 22-year old flyer by the Air Ministry. Several former studies had concluded that the gas turbine would be impossibly heavy. Unfortunately, these estimates were made by men who based their figures on steam turbines and thought of the gas turbine as an engine to drive a propeller. Whittle's idea *was* revolutionary; it eliminated the propeller; he wanted to push the airplane through the air with a jet of hot air rather than pull it with propeller blades. Anyway, the common opinion was that there were no materials which would stand the high temperatures that were theoretically necessary.

As one of the bright young men in the R. A. F., however, Whittle was sent to Cambridge University to study mechanical engineering. During this time three of his former friends and instructors organized Power Jets, Ltd., to commercialize

*Propellers rapidly lose efficiency at 400 miles per hr. and in rarified atmosphere. The true jet gains efficiency in the colder air at high altitude. As shown in the comprehensive discussion of gas turbines published in *Metal Progress* in September 1944, shortly after the information was taken from the "secret" category, a gas turbine takes in air, compresses it, and burns fuel in this compressed air. The hot blast then impinges on turbine blades, giving up only enough of its energy to drive the compressor, the remainder going out the tail pipe in a jet of very hot gas. The reaction forms the thrust which drives the craft forward.



The Olympus-Canberra, Powered by Two Bristol Olympus Turbo-Jet Engines

his inventions. He was permitted to give the firm six hours a week and on graduation in 1936 was assigned to "special duty" to continue the engine work. Meanwhile his friends had raised some private capital and the first engine was put on test in April 1937, less than two years after work started. It had one combustion chamber and developed 480 lb. thrust instead of the 550 lb. calculated. A rebuilt, 10-burner engine was the next step; the Air Ministry started to make small contributions and contracted with Power Jets for a flight engine, and with Gloster Aircraft Co. for a ship to fly it in. The first flight was on May 15, 1941; P. E. G. Sayer was pilot; it lasted 17 min. and the ship made 370 miles per hr. in level flight at 25,000 ft., well above the best the "Spitfire" could do.

This induced the government to make plans for quantity production of such an outstanding performer and the job was given to the Rover Co. Ltd., makers of automobiles, with unfortunate results. Later, Rolls Royce's aircraft engine department was brought into the project and its Whittle-type "Welland" engine saw some service in Meteor aircraft after August 1944 against V-1 bombs. Its ratings compared with the German jet fighter's as follows:

	Welland (Meteor)	Junkers (Messerschmitt)
Speed at sea level	410	520
Engine weight	850 lb.	1650 lb.
Thrust	1600 lb.	1980 lb.
Fuel consumption	1.12 per hr.	1.44 per hr.

Much of the book "Jet" is an account of troubles and misunderstandings with the Air Ministry and the commercial firms which were assigned the job of producing the engines. At any rate, Power Jets was kept in the status of a development organization and nationalized* at war's end. No doubt these disagreements, combined with excessive overwork, wrecked Whittle's nervous system and after periodic stretches of hospitalization he was retired from the Air Force in 1948, given an *ex gratia* award of £100,000 free of tax, and knighted. Possibly this was a fair reward for a man who – as he says in a footnote –"revolutionized aeronautics for the cost of two Comet jet airlines spread over eight years". He may have the added satisfaction of knowing that it is highly unlikely that at some future date a loyalty board will attempt to determine whether he can be trusted to advise his Queen's government about aircraft propulsion.

Whittle's book is designedly for the general reader, and makes small mention of the metallurgical problems encountered and studied by T. A. Taylor of his staff. The compressor rotor was cast by High Duty Alloys of aluminum alloy RR.56 (2 Cu, 1 Ni, 1 Mg, 0.9 Fe, 0.8 Si, 0.06 Ti). The first turbine wheel and blades were of Firth-Vickers "Stayblade" (20 Cr, 8 Ni, 1.2 Si, 1.3 Ti,

*That is, bought by the government – total private capital invested in Power Jets was £13,500 (pre-war; about $130,000 in 1954 dollars). The British government bought all outstanding stock for £135,-563 (1944 money; about $400,000 in 1954 dollars).

0.22 C); the same firm's "Rex 78" of higher creep resistance (18 Ni, 14 Cr, 4 Mo, 4 Cu, 0.65 Ti, 0.3 V, 0.07 C) was used after 1939, and by the end of 1941 Mond Nickel Co.'s "Nimonic 80" (20 Cr, 76 Ni, 2.5 Ti, 0.6 Al) came into use for the hot areas. Turbine blades were cut to shape in machines designed by J. A. Kestell of of United Shoe Machinery Co. Problems connected with the 20-fold rate of fuel consumption were solved with the help of a small Scottish firm, Laidlaw, Drew & Co., and I. Lubbock of Shell Petroleum Co.

The circumstance that so many firms participated in this development other than engine builders was repeated in Germany, as is clearly stated in Professor Schlaifer's "Development of Aircraft Engines". The pioneer there was a graduate student in aerodynamics, Hans von Ohain, who suggested in 1935 an engine like Frank Whittle's patent specification of 1930, of which he was completely unaware. The Heinkel aircraft factory was interested enough to build an experimental engine; in about a year a 550-lb. thrust engine was made at a cost of \$20,000. The world's first turbo-jet was a Heinkel and it flew Aug. 27, 1939, nearly two years before the Whittle-Gloster. Simultaneously, Herbert Wagner, of the Junkers Airplane Co., was building a jet engine of a different design; it was under test in mid-1938.

Space does not permit even an outline of the German wartime developments. Delay in getting the new fast aircraft into production was due to the Goering desire to make a large number of conventional aircraft for a short war. Messerschmitt jet fighters, each with two Junkers jet engines, did not come off the lines until early in 1944, but they immediately established superiority as a fast, short-range defender against anything the English or Americans could bring over Germany. About 1400 of them were built by the end of the war.

An extraordinary achievement in production and parsimonious metallurgy was these Junkers jet engines. The Air Ministry specified that no more than 500 man-hours be used per engine. Combustion chambers and other hot ducts were of aluminum-coated steel. The hollow turbine blades were made by welding two formed sheets of "Cromadur", a Krupp alloy containing 18% Mn, 12 Cr, 0.65 V, 0.5 Si, 0.2 N_2, 0.10 C, balance Fe. The turbine disk was a martensitic steel with no chromium or nickel. Turbine nozzles were hollow, and air cooled, of 12% chromium steel. The complete engine used no nickel and less than 5 lb. of chromium. That's conservation of strategic alloys for you! The engine had a short life – perhaps 25 hr. – so had the fighter in which it was installed.

America was years behind these other countries. We had the plant resources and N. A. C. A. test equipment; better alloys in the "Stellites" and "Hastelloys". Austenal Laboratories had solved the manufacturing problem of turbine blades by investment casting. However, we had no Whittle or von Ohain. Likewise, our airmen were interested in low fuel consumption and long-range aircraft, and so spent their time in improving piston engines and developing turbo superchargers for high-altitude flying. These are in fact turbines driven by hot exhaust gases, in turn driving compressors, but they did not need to operate at high efficiency since there was a large surplus of heat in the exhaust. We did not get into the jet business until late in 1941 when the British sent over the first Whittle test engine (now in the Smithsonian) and a set of drawings to General Electric's Lynn plant. The first American-built engine of this sort was flown in a Bell airplane on Oct. 2, 1942, but the real American effort was toward engines of much larger thrust – 3000 and even 4000 lb. None of these were in use by the end of the war.

The Schlaifer and Heron book is subtitled "Two Studies of Relations Between Government and Industry". Professor Schlaifer assumes that a development as costly as a jet engine would not be undertaken by private industry without a government guarantee or subsidy. (As a matter of fact, Brown-Boveri in Switzerland went it alone in their gas turbines, and the patent situation and Whittle's connection with the R.A.F. were probably the largest deterrent to private financing in England.) Serious delays were occasioned by bureaucratic interference and departmental jealousies in all three countries, even in wartime. Finally, the real spark-plug, the fundamental idea, came from Whittle and von Ohain and not from a civil servant.

Such facts and numerous other generalizations in the Schlaifer-Heron book would make good reading for anyone interested in today's pressing problem of the rapid development of atomic power for public use – the question whether the lead is to be taken by a governmental commission, no matter of how high a quality, or by private competition in a capitalistic economy, source of most of our living amenities.

Linings for Induction Furnaces

*By H. E. WHITE**

Magnesia-alumina mixes and zircon are now favored for special steels and high alloys. The author presents many "do's" and don'ts" for the melting superintendent, and backs up his advice with facts about properties of the minerals and the refractory manufacturing processes.

IN HIS FAMOUS monograph on "Principles of Inductive Heating With High-Frequency Currents", written in 1919, Prof. E. F. Northrup named silica sand, lime, magnesia, alumina, and zirconia as possible refractories for use in his furnace. He further stated, "When fine sand is used as a refractory, a thin wall of silica fuses about the molten steel and entirely prevents any flow or leak from the molten mass."

It would be nice if we could stop right here. It would appear there was no refractories problem 25 years ago. It is different now. Dr. Northrup could not have glimpsed the potentialities of his invention.

In most of the small, early furnaces, the metal was usually contained in graphite crucibles or the old "sand crucible"—that is, a clay crucible having siliceous material as the grog. Today, nonferrous (and some ferrous) metals are still melted in clay-graphite crucibles of special composition and the crucible itself is semi-conducting. Small melts of ferrous metals and alloys are usually melted in magnesia crucibles; alumina and zircon crucibles are sometimes used. Zircon is particularly useful where an acid refractory is desired. Beryllia and thoria serve in researches where contamination of metal must be kept to a minimum.

Except for the rare oxide refractories, the crucibles present few problems since their manufacture is now well standardized and they are easily and quickly replaced when they wear out.

Our present discussion concerns furnaces which are too large for the economical use of crucibles and which melt alloy steels and heat or corrosion resistant alloys.

In order to evaluate the available materials, it is necessary for the refractory manufacturer to know a good deal about the crystalline minerals now available, some in nature, most of them synthetic. This is especially true when the user makes a lining for himself rather than builds one up from the fired refractory shapes. We must separate the physical characteristics of the minerals themselves from the mass of data on fired shapes, since we are dealing with the aggregate itself. This requires some technical details but it is our premise that the more known about any material, the more efficiently it can be used. If longer life is to be obtained from linings, then their limitations must be known—their good as well as their bad points.

From our present knowledge of refractory materials, as well as their cost and availability, we are commercially limited to granular aggregates of crystalline alumina ("corundum"), crystalline magnesia (of the mineral periclase), silica (which has many names depending on its crys-

*Vice-President, Director of Research, Lava Crucible-Refractories Co., Zelienople, Pa. Portions of a paper presented before the Pittsburgh meeting of the Electric Metal Makers' Guild, Oct. 17, 1953.

stalline state) and zircon (the silicate). Zirconia (the oxide), beryllia and thoria are so far luxury items. Chrome ore or chromite is an unsatisfactory material because chrome refractory continues to shrink with use, and also has other disadvantages.

Hints on Furnace Linings

In the supplement we will give some of the physical data which confirm our belief that, for induction furnaces melting steels, high-temperature alloys, and corrosion resistant materials, the satisfactory commercial linings are now appropriate mixtures of magnesia and alumina or are of zircon. This is shown in Table I.

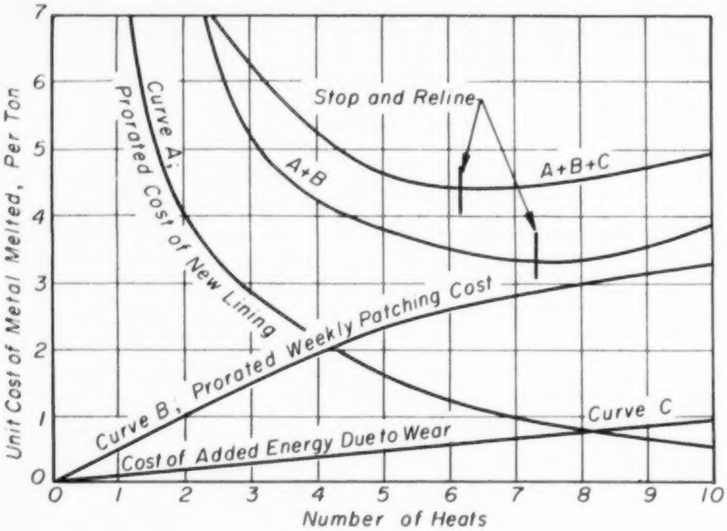


Fig. 1 – Curves Showing Economical Limits of Lining Maintenance

Now for the lining of the furnace in detail. Many operators have their own ideas and their individual practices undoubtedly work well for them. However, the following are some thoughts distilled from experience with many installations over a quarter of a century worked out in conjunction with the Ajax Electrothermic Corp.

First, let us take the coil itself: The refractory on the coil must *(a)* adhere to the copper coil; *(b)* it must not contain electrically conductive materials nor water-absorbing materials such as sodium silicate, chlorides or phosphates; *(c)* it must air-set and stay hard, and *(d)* it must resist metal break-throughs.

The best practice is to coat the coils with an adhesive alumina cement—one that does not carbonize on heating—then ram the spaces between the coils with a nonshrinking, grog-type, mullite plastic, and coat the entire inside cylin-

Table I – Relative Service Figures of Linings

Type of Alloy Melted	Type of Lining	Size of Unit, Lb.	Life in Heats	Type of Operation	Pouring Temperature	Remarks
Stabilized stainless steel	Magnesia-alumina, 60-40	2,000	60 to 170	Intermittent	3,000 plus	Some patching done
Stainless steel	Magnesia-alumina, 60-40	4,000	More than 100	Intermittent	2,950	Little patching
Ni-Cr and Mo-V-Mn steel	Magnesia-alumina, 60-40	1,000	30 to 40	Intermittent	3,000 plus	No patching
Stainless steel Ti-Co-W	Magnesia-alumina, 60-40	4,000	70	Intermittent	3,000 plus	Some patching
Heat resisting Ni-Cr-Fe with Ti, Co, W	Magnesia-alumina, 70-30	4,000	80 to 90	Intermittent	2,950	Some patching
Heat resisting alloys	Magnesia-alumina, 70-30	1,000	15 to 20	Intermittent	3,000 plus	Some patching
Low-carbon steel	Zircon	3,000	30 to 50	Continuous	2,950	No patching
Stainless steel	Zircon	2,000	60	Continuous	3,100	Some patching
Jet engine parts	Zircon	1,000	90 to 150	Intermittent	3,050	Considerable daily patching

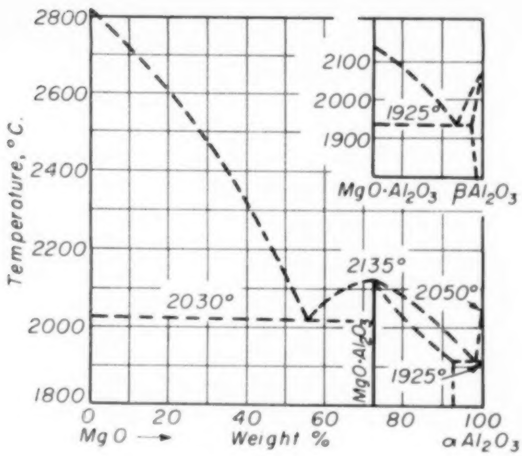


Fig. 2 – The MgO-Al_2O_3 Binary System

der and outside with adhesive cement. In this way the whole coil is kept rigid and is protected; furthermore, fine steel or iron particles are kept away from the surface of the copper coil.

CAUTION – Be sure the coil supports are in good shape and not charred.

The Lining Itself – First, secure a good form. (In small furnaces the crucible acts as the form.) A good radius at the bottom edge is quite necessary but the bottom should be flat so that the refractory can be well compacted in this region. Depending on size of the furnace, the radius blending the bottom to the side should be proportioned so the rammer can properly knit the bottom zone to the side walls.

If you melt out the form, make it of steel sheet or thin plate and only tack weld it together for some flexibility – a completely welded, stiff form might disrupt the lining by its expansion when heating it the first time. Transite or asbestos forms are also used with good results but are more expensive than steel.

The dimensions should be the proper ones specified by the furnace manufacturer. Any deviation either way is uneconomical. Too thick a lining reduces the furnace efficiency, let alone the capacity; too thin a lining imperils the coil. A tapered liner is better than a straight cylinder since it is easier to remove and gives a somewhat thicker lining in the bottom area.

The ramming tool should have a face 3x1¼ in. or smaller. A chipping air hammer with a short stroke should be used; air pressure should be 80 to 100 lb.

During lining the water in the coil should be at about 100° F. to prevent any water from condensing in the refractory adjacent to the coil. Thermostatic valves controlling the coil line are advisable.

As mentioned above, the most popular and most generally serviceable lining is the magnesia-alumina type. Zircon linings, used early in this work by Dr. Northrup but now improved in both bond and aggregate, are finding their place in many applications. These two types constitute almost all the induction furnace linings in this country.

Such linings are handled somewhat like plastic materials. Most of the magnesia-alumina mixtures are rammed dry in layers about 2 in. thick. However, dry ramming is not absolutely essential; up to 2% water may be added and a removable form used if care is taken in the drying. Zircon is usually rammed in a slightly damp state and the form removed.

First, ram in the bottom well and roughen up the edges, then place, center and weight the form down heavily. It is important to hold the form in correct position.

Then proceed with the lining operation, layer by layer. Density is very important but don't over-ram, as particle segregation may result. It is important to remix any lining material before using. Some weird examples of segregation have been observed during short truck hauls to transcontinental shipments.

When the lining is completed, it is usual to seal the top with a good air-setting cement such as used on the coil. This helps hold the lining in place and counteracts the upward pressure from molten metal. It also resists mechanical abrasion during charging.

On the first heat as well as on subsequent heats put the heavy parts of the charge in the bottom and feed the light scrap later. This early precaution vitrifies the lining by getting the power in the proper place at the right time and gets the lining off to a good start.

Maintenance and Repairs

There is no problem in maintaining graphite crucibles. With some extremely high temperatures, small surface hair cracks or checks may develop, but a wash of high alumina cement will not only seal these over but keep the crucible clean in subsequent melt by causing any slag to part from the surface.

Due to its various changes of crystal state, silica (ganister) is a good packing material between the coil and the graphite crucible. It does not sinter readily at operating temperatures.

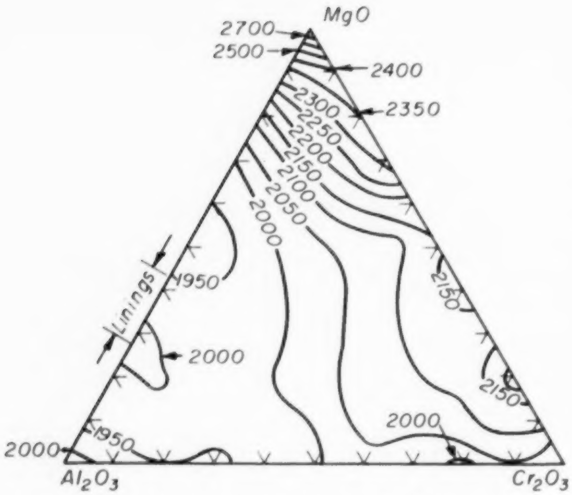


Fig. 3 – Melting Points of the $MgO-Al_2O_3-Cr_2O_3$ System. Isothermals noted with °C.

The same remarks about maintenance are true of crucibles other than graphite. Cements of alumina, zircon, and magnesia are available for sealing minor cracks and filling in washed-out places. Backing material should be similar in composition to the crucible.

Linings – In the larger furnaces it is very difficult to maintain linings under 24-hr. operation and it has become quite common to double the number of units so furnaces can be alternated day to day, repairing the ones which are down.

With magnesia-alumina mixes one can make some emergency hot patches in sidewalls by putting in a partial charge to blanket the heat and then bracing a piece of sheet iron against the spot requiring patching, and tamping some of the original lining material into the cavity back of this. Use a solution of boric acid to bond the lining material or a prepared patching material of the same type as the original lining.

Excess slag may be removed on down furnaces that are relatively cool. Do not break all of it away down to the original mix – just the warts and adhesions. (This is true for zircon as well as magnesia-alumina linings.) Wash the lining with a prepared fine-grained slurry containing an adhesive bond, and then patch deep depression with a coarse mix, hand-troweling the material into place. Finally, wash with the fine-grained mix. (Some melters do not use it, but since the demand for the fine mix is increasing, it must work and it does help.)

Patched linings must be dried overnight with electric strip heaters or a low gas fire.

For patching, up to 25% of old material in good condition from the backing of worn-out linings can be utilized provided no metal or slag particles are included. One-half to two percent (0.5 to 2.0%) of a saturated solution of boric acid or 1% of silicate of soda may be added for bond. A saturated solution of boric acid (commercial grade) is about 25 parts by weight to 100 parts of water.

There is a tendency to overdo the patching idea. In some instances more patch is used than the quantity of original lining material remaining in the furnace. Figure 1 is a set of curves made by the author some years ago showing the fallacy of this.

Do's and Don'ts for Induction Furnaces

Don't leave metal heels in the furnace.

Remove slag as made.

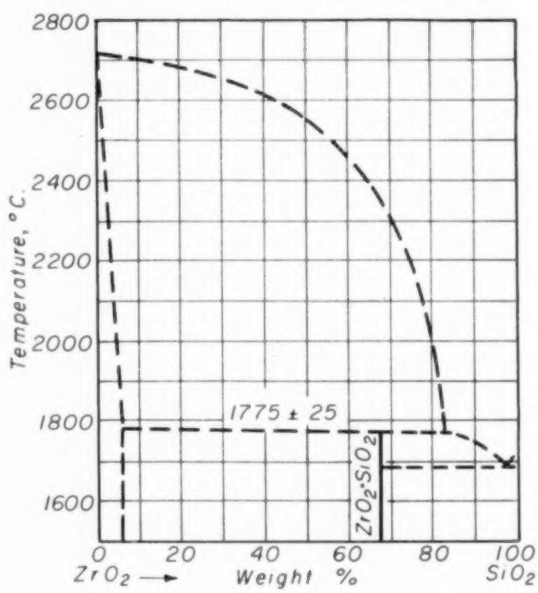
Keep down bridging.

If the bottom comes up, shut the furnace down; it is almost impossible to patch a poorly installed bottom.

Run melts at different levels to distribute slag action and minimize its effect.

Slag Attack – With these very thin linings, the slags must be kept at a minimum. Magnesia is,

Fig. 4 – The ZrO_2-SiO_2 Binary System According to Geller and Yavorsky, National Bureau of Standards, Research Paper 1662 (1945)



of course, basic and zircon is acid. The magnesia-alumina mixture is a very close to neutral in its reaction.

Further than this, the method of installing and the efficiency of the operation of individual installations has a greater effect on slag resistance than most other factors. This is particularly true about the top area.

Equilibrium Diagrams

Now let us take a quick look at some of the scientific facts underlying the best refractories for induction melting of iron alloys. We can start with the pertinent equilibrium diagrams, remembering that they apply to highly purified components rather than more impure natural minerals. Oddly enough, the two types of lining materials that are most used are, or eventually become, binary compositions—namely, magnesia-alumina (forming on use a synthetic spinel) and zircon, a natural binary mineral.

Figure 2 shows the magnesia-alumina binary diagram. The mixes recommended in Table I (60-40 and 70-30 MgO-Al_2O_3) are to the left of the $MgO \cdot Al_2O_3$ compound, and if the minerals were pure, melting would not commence until the mix reached 2030° C. (3690° F.)—ample for our uses.

The magnesia-silica binary system shows a low point at 1543° C. (2800° F.) for mixes containing more than 60% SiO_2, indicating the advisability of keeping away from this range of composition. We stress this point because there are some lining materials made from converted olivine, a natural magnesium silicate plentiful in the southern states and relatively low in refractory value. At high temperatures olivine becomes mainly the mineral forsterite—existing also in electrically fused magnesia in small quantities. Silica in the latter must be kept below 3%, else the forsterite which forms acts as a lower-melting lubricant between the periclase grains.

Figure 3 shows the reason why there is a heavy slag build-up on magnesia-alumina linings when melting heats containing chromium. Any chromium oxides may combine with the magnesia and alumina forming a refractory slag; isothermals show that Cr_2O_3 does not lower the melting point of the $MgO \cdot Al_2O_3$ combination. Iron oxide is also absorbed by the magnesia in appreciable amounts without lowering its melting point. Application of a zircon wash in the upper area of the lining will facilitate removal of the slag ring.

The binary ZrO_2-SiO_2 diagram (Fig. 4) shows

Fig. 5 – Pouring Alloy Steel Castings From Induction Furnace. (Battelle Memorial Institute)

a rather low-melting eutectic with over 95% SiO_2, but this is of little interest to zircon refractories. They conform to the compound $ZrO_2 \cdot SiO_2$, which has a change point and incipient melt at 1775° C. ± 25 (3250° F.). What little work has been done on the ternary diagrams indicates some lower-melting eutectics with alumina.

Physical Properties of Commercial Refractories

The equilibrium diagrams do not, of course, tell the whole story. There are some unusual mineralogical characteristics encountered in the materials now in use. We must rely on the evident compounds formed rather than on the melting points of the individual oxides.

Thermal Conductivity – Magnesia, in its crystal form, has higher thermal conductivity than zircon. As shown in Fig. 6, the order of increasing conductivity is zircon, silica, alumina, and magnesia. However, this order is not followed, necessarily, in the crushed and prepared aggregate, since the packing of the material is an important factor.

For example, some very excellent work was done at Massachusetts Institute of Technology and published in the *Journal* of the American Ceramic Society in 1954 concerning fine-grained crystalline materials formed into shapes and fired. The data were then calculated to zero porosity and show that silica has somewhat lower conductivity than zircon. For example, at 1200° C. (2200° F.) silica has a conductivity of 0.008 cgs. units whereas zircon has 0.0098.

Electrical Resistivity – Figure 7 shows the increasing order of resistivity to be zirconia, silica,

zircon, alumina, and magnesia – the magnesia having by far the greatest resistivity. Alumina and magnesia have very low electrical conductivity at temperatures less than 2000° C.

The low electrical resistivity of zircon may be indicated in the electrical circuit of the induction furnace, when compared to one lined with magnesia of high resistivity.

Zirconia becomes a conductor at 1500° C. (2730° F.) and is therefore used for heating elements at high temperatures as well as susceptors in ultra-high-frequency induction furnaces.

Electrical resistance of oxides usually decreases with increasing temperature; with metals, the reverse is true.

Thermal Expansion – Silica is notoriously fickle; it has at least eight crystalline modifications, most of them with high expansions. There is also a very large expansion when alpha cristobalite transforms to beta. Quartz glass, on the other hand, has a much lower thermal expansion.

In general, it may be said that graphite has the lowest thermal expansion of all commercial refractories, about one third that of zircon, alumina and stabilized zirconia. Magnesia has the highest expansion.

Recent results are summarized in Fig. 8.

Notes on Commercial Refractories

Silica is very seldom used to line coreless induction furnaces in this country, but is used to a certain extent abroad.

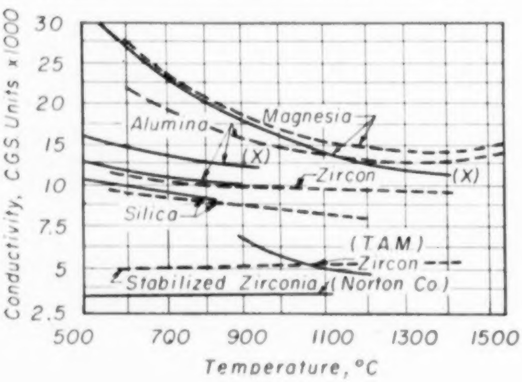
Magnesia-Alumina – Both natural magnesia and alumina shrink continuously at high temperatures unless they have been previously completely converted to the crystalline state by fusion. Crystalline magnesia has, moreover, the property of absorbing several times its own weight of iron oxide without seriously impairing its use as a refractory. This distinctive property is possessed by no other known refractory.

Many years ago it was found that crystalline magnesia and crystalline alumina work best in combination, forming – as time at temperature progresses – a very refractory spinel. J. H. Chesters, discussing induction furnace linings in his well-known book on "Steel Plant Refractories" gives some data on the firing expansion of these mixtures, and finds that the 30-70 ratio (approximately pure spinel, $MgO \cdot Al_2O_3$) has the highest firing expansion of 9.4%. On the other hand mixtures with less than 40% Al_2O_3 are quite stable in size under continuous heating. (Fig. 9).

He further states that the expansion is due to the fact that the specific gravity of the spinel is considerably less than the average specific gravity of the constituents, and the reacting grains are forced apart when spinel forms at the interface. One practical result is that this reaction causing permanent expansion takes place to a large extent on the inner face of the lining where it is hottest and actually tends to hold the lining rigid – at the same time increasing the resistance to the slag.

Zircon – Chesters has this to say in his chapter on induction furnaces (p. 376 of the 1946 edition): "Zircon shows marked possibilities since it

Fig. 6 – Thermal Conductivity of Crystalline Refractories. Dashed lines from Journal of the American Ceramic Society for 1954, part II; full lines from same journal for 1938 except those marked (×), which are from American Institute of Mining and Metallurgical Engineers' Technical Publication No. 817



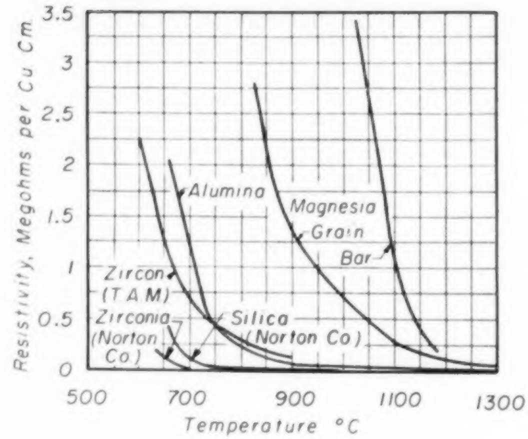


Fig. 7 – Curves of Electrical Resistivity of Crystalline Refractories (Journal of the American Ceramic Society, 1938)

does not shrink when fired, is highly refractory and resistant to slags high in iron oxide. The difficulty in its use lies in finding a suitable bond, such materials as fireclay being readily attacked and the undissolved zircon grains float out into the melt."

That was written in 1946, and is contrary to the trade literature on American refractories, which states that the presence of iron oxide in the melt reduces the life of the lining considerably. While the melting point of zircon is high, it begins to dissociate into zirconia (ZrO_2) and silica glass at about 2800° F. When heated for an extended period about 3100° F., the dissociation is practically complete; higher temperatures volatilize the silica and at the end we have a fused zirconia. Zircon is not recommended, therefore, for use above 3200° F. (1760° C.); however, it

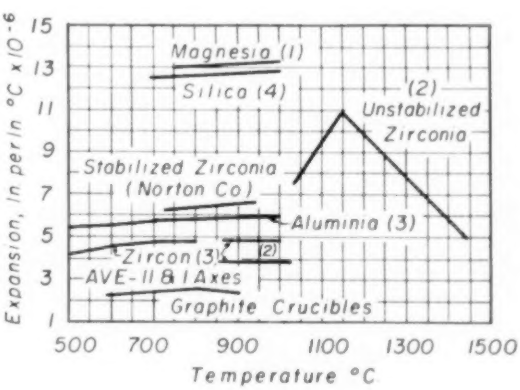


Fig. 8 – Variation of Linear Thermal Expansion With Temperature. References: 1 and 3 – Journal American Ceramic Society, 1938 and 1931 respectively; 2 – Titanium Alloy Manufacturing Division's Booklet; 4 – Harbison-Walker Refractories Co.'s "Modern Refractory Practice"

has been used successfully in short runs at much higher temperatures.

A leading manufacturer's booklet states that under reducing conditions up to 2900 or 3000° F., it is possible to dissociate zirconium silicate (zircon) and transfer silicon and zirconium to the melt. The present author has not substantiated this statement.

Zircon also reacts at high temperature with the oxides of iron or copper – the lower oxides more readily than the higher. In general, zircon is not appreciably affected by ferrous metals themselves. However, the oxides of iron that may be present in low-carbon steel or in the charge, do attack. Medium-carbon and high-carbon steels do not usually give this difficulty. Zircon is an acid refractory and it should not be used in contact with basic slags.

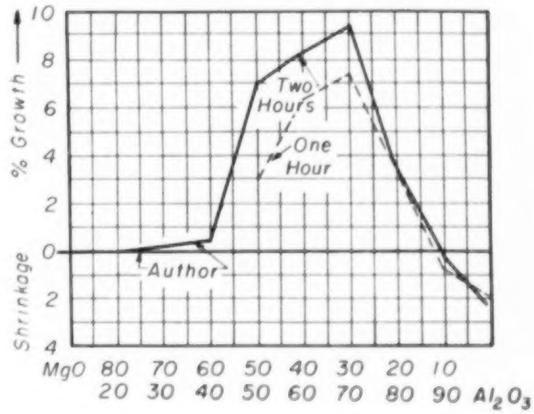
The mineral zircon is the silicate and should not be confused with zirconia, the stabilized oxide. Zirconia of 98 to 99% purity has a melting point of approximately 5000° F. (2765° C.). Changes in crystal form take place at about 2100° F. (1150° C.) into the high-temperature monoclinic form. Monoclinic zirconia is reconverted into the stable cubic crystal by reacting it with a small percentage of certain oxides, the common one being lime. There is little or no reduction in melting point. Zirconia in its stabilized form is quite expensive and its relatively high electrical conductivity may cause trouble in linings for induction furnaces.

Beryllia, at present not plentiful, has low electrical conductivity but high thermal conductivity, the reverse of zirconia. Perhaps some day a useful combination of these might be worked out.

Chrome refractories unfortunately shrink and vitrify continuously at high temperature. Under some conditions they also disintegrate. Combinations of chromite with another oxide, similar to the combinations of alumina and magnesia, have not been successful as induction furnace linings, even though combinations with other minerals have made good refractory brick as well as fused-cast refractories.

Aggregate Shape and Packing – The average grain size and shape and grain size distribution have a great deal to do with the density of the furnace lining. Crystalline magnesia is the prod-

Fig. 9 – Permanent Growth of MgO-Al_2O_3 Mixtures after Heating to 1600° C. (2910° F.) for 1 or 2 Hr. (Chesters, "Steel Plant Refractories", and present author)



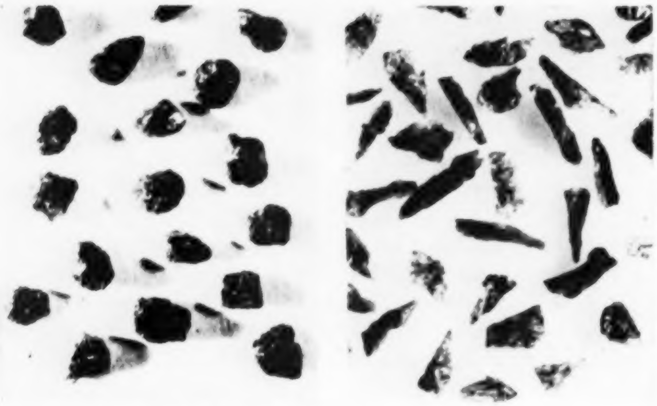


Fig. 10 – Fused Alumina Particles From Two Types of Crushers. Natural size

uct of fusion, so it is possible to have any grain size. Moreover, the crystal itself is blocky and solid, so the material is crushed and carefully sized. This operation is most important; slight changes in the equipment and routine make large changes in the product. For example, Fig. 10 shows magnified views of fused alumina grain from two different types of crushing. Obviously particle packing and particle shape have a great influence on any compact.

On the other hand, the mineral zircon is a fine sand (Fig. 11) typically 89% through 100-mesh screen. To secure the coarse aggregate necessary for furnace use, the sand must be synthetically bonded, fired, crushed, and screen-sized.

If all particles could be crushed in cubical shape and packed cubically, the porosity of the resultant body would be zero, provided that air absorption were negligible. (Carbon black may have as high as 95% air in the voids about the particles; incidentally, it is a good heat insulator for this reason.)

If spheres are packed so their centers are arranged on a cubic lattice, the percentage of voids is the same whether there is one sphere or a number of spheres of equal size, provided their diameters are exact multiples and each sphere is directly on top of the one below it. The voids are then 47.6% of the whole. By different arrangement of the spheres, as in a hexagonal lattice, this can be reduced theoretically to 26%. By fitting in smaller spheres up to five stages, the actual theoretical porosity can be reduced to 3.9%; even then, the primary spheres still constitute 77% of the mass.

It is, of course, impossible commercially to attain either these shapes, sizes, or packing. Actually, porosities as low as 10% have been attained on a laboratory basis, but figures of 15 to 20% are normal. Magnesia-alumina linings usually measure 18 to 25% in porosity, and zircon linings 20 to 25%.

Since the shape of the particles plays an important part, well-rounded sand grains have 2 to 5% less voids than corresponding sharp grains.

The effect of moisture is also unexpected. Moist sand occupies more space per unit weight than dry sand packed in the same manner, since the film of water coating each grain is thicker than the corresponding film of air.

The pore space in an aggregate, then, depends on the ratio between the size of the particles, their shape, and their packing arrangements. Surface areas and the porosity of the grains themselves must be considered. Some commercial refractories which have relatively low porosity seem to have been made by men who knew a good deal about the laws of particle packing, both in the manner of packing of the grog grains and in the shape of the grains themselves. At any rate, it is always well to remember that in any mixture of grains it is always difficult to get the highest density without some segregation of mineral or of shapes. Here again is the warning that all materials should be carefully and thoroughly mixed just before being placed.

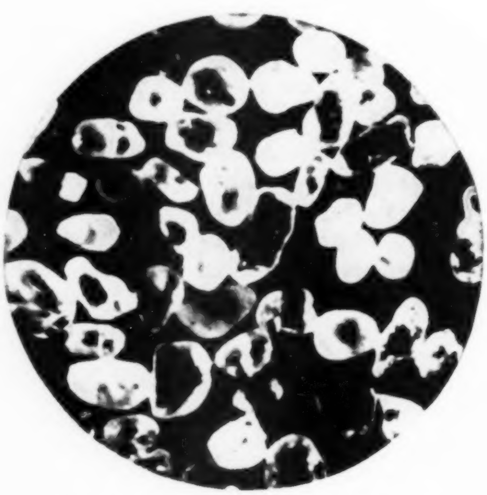


Fig. 11 – Grains of Zircon Sand, 50 ×

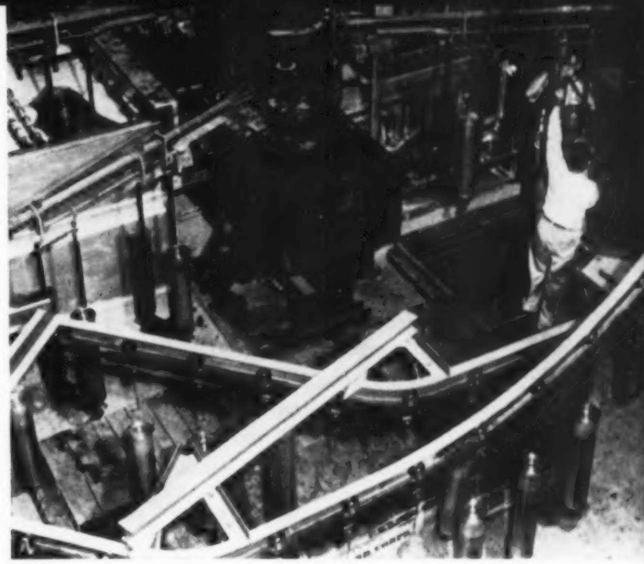


Fig. 1 — Loading and Unloading Station of Hanson-Van Winkle-Munning Automatic Plating Machine at Riverbank Ordnance

Procedures and equipment used at Riverbank Ordnance to plate cartridge cases.

Automatic Zinc Plating

*By C. E. FISHER and D. F. ZLATNIK**

WHEN the use of steel in place of brass for cartridge cases was proposed so as to conserve the wartime supplies of copper and zinc, one of the limitations of this subsitute which had to be overcome was its low resistance to corrosion, especially in marine atmospheres. According to Specification O.S. 1394, "Specifications for the Corrosion Resistance Requirements of Steel Cartridge Cases", published by the U.S. Naval Gun Factory, these requirements are as follows:

1. No process shall be approved by the Bureau of Ordnance which involves a coating which will react with or in any way affect the propellant or any other ammunition component with which it may be in contact in service.

2. No process shall be approved which requires an application of material greater than 0.0005 or less than 0.0002 in.

3. All cartridge cases shall withstand a 20% salt spray at room temperature for 120 hr. without exhibiting rust from the base metal, and shall not show any accumulation of corrosion products (from the decomposition of the coating itself) sufficient to prevent their gaging. The coatings used shall withstand the corrosion ordinarily produced by contact of dissimilar metals at the mouth and primer chamber. The coating shall also prevent any formation of rust when the cases are scratched through to the steel.

4. All coatings shall withstand deformation without any loss of adherence, flaking or peeling.

5. All coatings shall be free from imperfections such as uncoated areas, scratches, abrasions, checking or peeling.

The contractor is permitted some latitude in the establishment of a process for applying the protective coating on steel cartridge cases, but it must first receive the approval of the Bureau of Ordnance. The process selected for use at the Riverbank Ordnance Plant (operated by Norris-Thermador Corp.) has three functions: *(a)* preparation of the surfaces for zinc plating, *(b)* application of the zinc plate by electrodeposition in an alkaline cyanide plating bath, and *(c)* application by electrolytic action of a zinc chromate conversion film to the zinc plate. Twenty-three operations listed in Table I are needed to accomplish these basic functions on the 5-in. 38-caliber cartridge cases shown in Fig. 1. (The operation shown in the illustration is the loading of the cases for processing in the automatic plating machine manufactured by Hanson-Van Winkle-Munning Co., Matawan, N.J.) Figure 2 shows the arrangement of the processing stations around the central conveyer structure.

*Mr. Fisher is quality control manager, and Mr. Zlatnik is chief process engineer, Riverbank Ordnance Plant, Riverbank, Calif.

Preparation of Work for Zinc Plating

Cathodic Electrocleaner—This operation removes grease, oil and other soil to assure uniform acid pickling in a subsequent operation. A solution of 8 oz. per gal. of a proprietary alkaline cleaner compound operated at a temperature of 140° F. is employed. A current density of 30 amp. per sq.ft. produces the desired cleaning action. Although the work can be made anodic in this operation, best results are obtained with the work cathodic.

Overflow Rinses—Fresh water is continuously pumped into each of the two overflow rinse tanks that follow the electrocleaner to reduce contamination with rinsed-off chemicals to a minimum. Top sprays are used for additional rinsing action in the second tank.

Pickle—The film of iron oxide at the mouth of the cartridge cases is removed by pickling in a 10% solution of sulphuric acid at 150° F. A pickling inhibitor is added as required to prevent excessive attack on the steel underneath the oxide.

A second pickling operation (similar to the preceding) removes acid-soluble soil and superficial oxides from all surfaces of the work. A wetting agent as well as an inhibitor is used in this pickling solution. The wetting agent increases the effectiveness of the inhibitor. A cold rinse and spray follow.

Anodic Electrocleaner—The second electrolytic cleaning removes pickling smut, acid insoluble soil, and iron salts which may be formed from the pickling action. A somewhat stronger (12 oz. per gal.) solution of the same proprietary alkaline solvent as used in cathodic cleaning is employed in this one and at the same temperature (140° F.). The work in this operation, however, is made anodic to prevent the electrodeposition of any metallic impurities present in the solution. The remaining steps in the cleaning cycle are a fresh water rinse, acid rinse and then two more rinses in running water. The acid rinse is a 10% solution of sulphuric acid without inhibitor, operated at room temperature. Its purpose is to remove any oxide films caused by the action of the electrocleaner.

Zinc Plating

There are four factors over which close control must be exercised to assure the continuous production of a satisfactory zinc coating: (*a*) current density of the internal and external plating circuits, (*b*) composition of the plating solution, (*c*) temperature of the plating solution, and (*d*) maintenance of the workholders.

The first of these is controlled by adjustment of the voltage controls of the direct-current generators to obtain the prescribed current density on each circuit. Representative samples are examined daily to determine that the plating thickness meets the requirements of the specification. A coating 0.0003 to 0.0004 in. thick is deposited with a current density of 35.0 to 37.5 amp. per sq.ft. of surface to be plated.

The plating bath is a conventional cyanide zinc solution maintained at the following nominal concentrations: sodium hydroxide, 15 oz. per gal.; sodium

Table I – Operations in Automatic Zinc Plating at Riverbank Ordnance Plant

Sequence of Operation	Processing Solution	Concentration	Time, Sec.	Temperature	Current Density*
Cathodic clean	Turco Prosolv B	8†	56	140° F.	30
Overflow rinse	Water		11		
Overflow rinse	Water		11		
Mouth pickle	Inhibited H_2SO_4	10%	191	150	
Over-all pickle	Inhibited H_2SO_4	10%	101	150	
Over-all rinse	Water		11		
Over-all rinse	Water		56		
Anodic clean	Turco Prosolv B	12†	56	140	30
Overflow rinse	Water		11		
Acid rinse	Inhibited H_2SO_4	10%	11		
Overflow rinse	Water		11		
Overflow rinse	Water		11		
Zinc plate	NaCN	‡	416	90	35
Reclaim	None		11		
Reclaim rinse	Water		11		
Overflow rinse	Water		11		
Overflow rinse	Water		11		
Overflow rinse	Water		11		
Anozinc	Anozinc	32†	186		10
Overflow rinse	Water		11		
Overflow rinse	Water		11	125	
Dry	None		236	150	

*Amp. per sq. ft. †Oz. per gal. ‡Sodium hydroxide 15 oz. per gal.; sodium cyanide 15 oz. per gal.; zinc 5.5 oz. per gal.; sodium cyanide to zinc ratio 2.75.

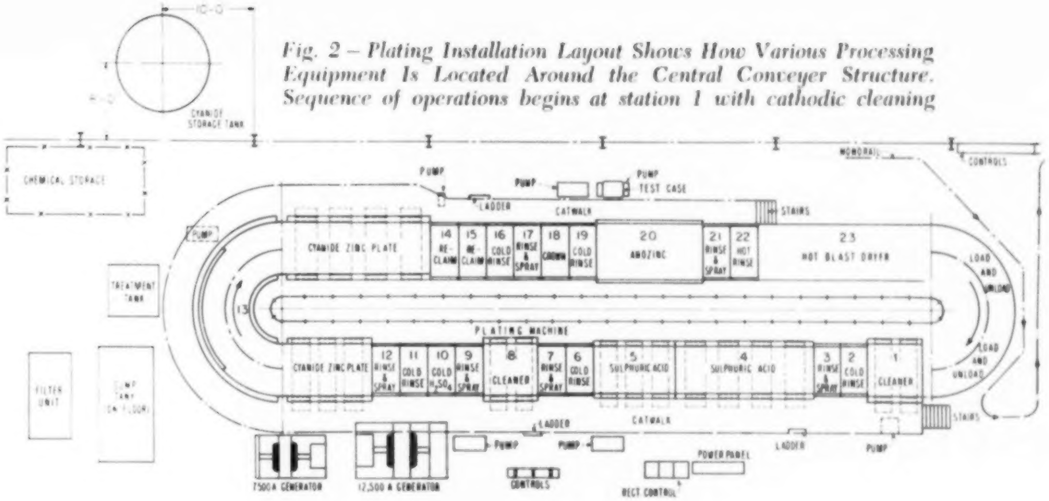


Fig. 2 – Plating Installation Layout Shows How Various Processing Equipment Is Located Around the Central Conveyer Structure. Sequence of operations begins at station 1 with cathodic cleaning

cyanide (total), 15 oz. per gal.; and zinc metal, 5.5 oz. per gal.

Although the large volume of the plating bath (10,700 gal.) prevents rapid changes in composition, a chemical analysis is made during each 8 hr. of its operation. Additions of caustic, cyanide and zinc anodes are made daily to replace the losses from drag-out of solution and electrodeposition of zinc. The ratio of sodium cyanide to zinc metal is maintained at 2.75.

Contamination of the bath is caused by the formation of carbonates and dissolving of certain metals. Carbonates, formed as the result of a reaction between the plating bath and air, build up very slowly and are removed at infrequent intervals. The is done by adding hydrated lime to produce insoluble calcium carbonate which is precipitated, washed to recover soluble cyanide, and dumped.

Metal impurities usually occur as lead or cadmium, small amounts of which can seriously affect the appearance and corrosion resistance of the zinc plate. Analysis of the solution is made each day to determine the presence of such contaminants. These are precipitated as metal sulphides by small additions of polysulphide and are subsequently filtered out of the solution.

Nominal operating temperature of the bath is 90° F., this being maintained by automatic steam regulators in the feed line to the heating coils in the plating tank. Poor quality work is sometimes encountered even though current density, solution composition and temperature are under control. The cause is usually traceable to the workholders. Misalignment of the workholders, worn or improperly adjusted electrical contacts (which also support the cases) or corroded conveyer arms or hangers for workholders are the most common sources of trouble. Periodic inspection and repair is the most satisfactory way of preventing such difficulties.

Because drag-out of the plating solution on the work and workholders is substantial, a tank is provided into which the excess can drip. The reclaimed solution is returned to the zinc plating tank as it accumulates.

The plated articles move to a reclaim rinse which removes most of the plating solution remaining on the work and the workholders. This rinse water is pumped into the plating tank at the end of each shift to partially replace the losses by evaporation. Following this are two more rinses, both in tanks having top sprays to provide maximum rinsing action.

The plating machine can apply a chromate conversion film to the zinc plated surface either by an acidified dip (Cronak) or by electrolytic action (Anozinc). As presently operated, the Anozinc process is employed.

Application of Anozinc

The process for the zinc chromate conversion film utilizes proprietary chemicals made by United Chromium, Inc. Concentration of the process solution is measured by specific gravity determinations and by titrations with an alkaline reagent. Close control is also maintained over the pH of the solution (5.5 to 6.0). The work is made anodic for the electrolytic deposition of the Anozinc film.

Thickness of this film is directly proportional to the current density since the other factor, du-

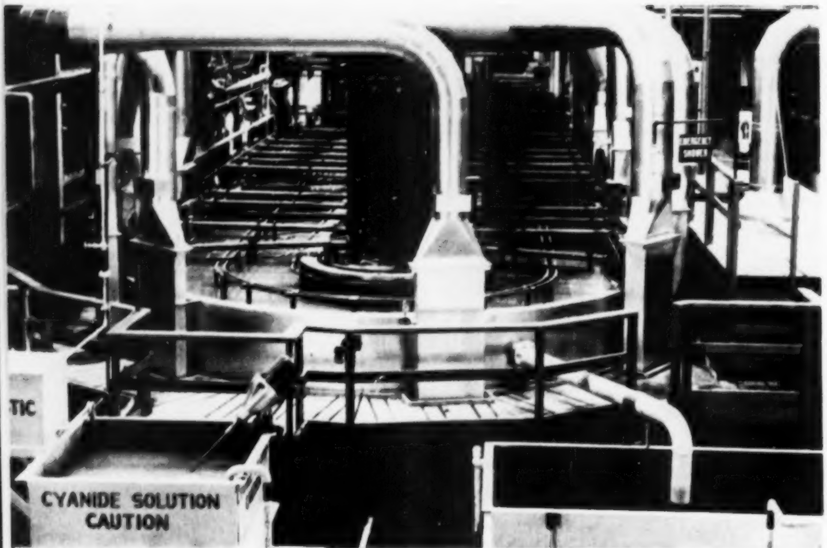


Fig. 3 – Automatic Plating Machine as Seen From the Plating Tank End. The J-shaped zinc plating tank is at the center of the illustration and the various plating solution processing equipment is in the foreground. Note extensive ventilating duct system for disposing of noxious fumes

ration of exposure, is constant (being determined by the dwell cycle of the machine). Current density is maintained between 10 and 15 amp. per sq.ft. of work surface. Appearance and adherence of the film also are functions of the current density. Low density will produce very pale, irridescent films; excessively high density will yield deep yellow, nonadherent coatings.

Top sprays are used with the first of the two final rinses, air jets with the second rinse to blow off the pool of water from the head surface of the work. This promotes drying of the cases in the next operation, in which air that has been heated to about 150° F. is discharged through ⅜-in. diameter jets against the external surfaces of the cases. Their interiors are dried by air that is conducted through the workholder inert anode to the inside of the cartridge case. The warmed air is recirculated to the blower.

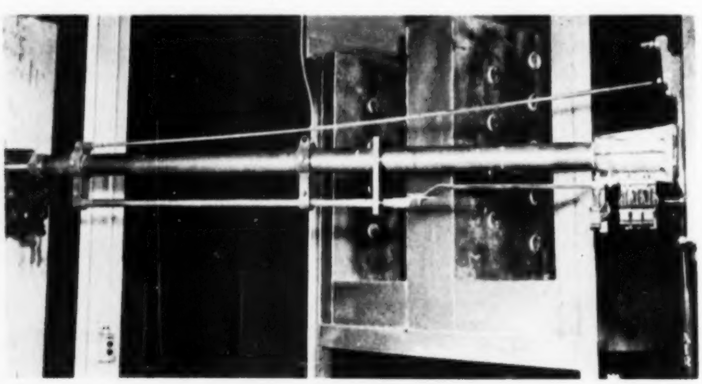
Automatic Plating Machine

The equipment required to perform the operations shown in Table I is quite extensive and complex, so only a brief description of its more general components can be attempted in this article. Work is moved through all of the cycles of the Hanson-Van Winkle-Munning plating machine by an elevator or "jack rabbit" type conveyer which has a vertical lift of 54 in. and a forward transfer of 36 in. during each cycle. Two separate drive systems are provided, one for operation of the elevator lifting mechanism, and the other for operation of the forward transfer.

Transfer time, including lift, forward transfer, and drop of the conveyer, is 34 sec. Dwell at the end of each transfer (with conveyer in lowered position) is adjustable between 0 and 120 sec. and is set for 11 sec. dwell for plating of the 5-in. 38-caliber cartridge cases. Unit cycle time is equal to dwell plus time for transfer, in this instance 45 sec., and is the controlling factor in the production rate.

The conveyer is equipped with 50 copper carrier arms extending outward from the central structure which supports the conveyer and the mechanism for the conveyer drive. The purpose of the carrier arm is to support workholders carrying the work and to conduct the electric current from busbars to the workholders. Each arm is of bipolar construction consisting of a large weight-carrying member to which a smaller mem-

Fig. 4 – Conveyer Arm Showing Bipolar Construction and Electrical Pickups for Making Contact With Busbars



ber is attached by means of insulated couplings as shown in Fig. 4.

Each member of the conveyer arm is equipped with sliding-shoe electrical contacts which make up the electrical circuit with busbars mounted on the central structure. Current to the busbars is supplied by motor-generator sets for the zinc plating operation, and by individual rectifier units for each of the electrolytic cleaning operations and for application of the Anozinc.

Two bipolar workholders are suspended from each conveyer arm. The workholder (Fig. 5) is constructed of two copper bars, the right angle ends of which are insulated from each other by a Teflon gasket, and the open ends of this U-shaped framework are formed into hangers. Two copper bars are brazed crosswise to the framework, one to each side of the insulated connection. A nickel yoke is attached to both ends of one of these crosspieces. Two bronze electrical contacts (which also support the cartridge case) are threaded into the nickel yoke. An Inconel tube, which serves as an internal inert electrode during zinc plating, is attached to each end of the second crosspiece and extends through the yoke and upward inside the steel cartridge case.

A Teflon insulator and the rack coating material prevent short circuiting between the yoke and the electrode. With the exception of the electrical contacts and the internal electrode, the workholder is coated with approximately ⅛-in. thick vinyl resin protective material (Belke No. 570).

Each workholder holds two cartridge cases which are placed mouth down over the internal electrode. This position causes an air bubble to be trapped inside the head of the case between the primer boss and the sidewall that would prevent processing that portion of the case. To correct this difficulty the bottom of the electrode has a funnel (Fig. 6) which collects processing solution from vertical jets suitably located in horizontal manifolds in the bottom of the processing tanks. The collected processing solution is forced through the hollow electrode and out the top. A double-cone head (with spiral-shaped vanes between the cones) at the top of the electrode directs this solution into the air pocket inside the cartridge case head and imparts a swirling action which displaces the air bubble so that all surfaces are subjected to the processing solutions.

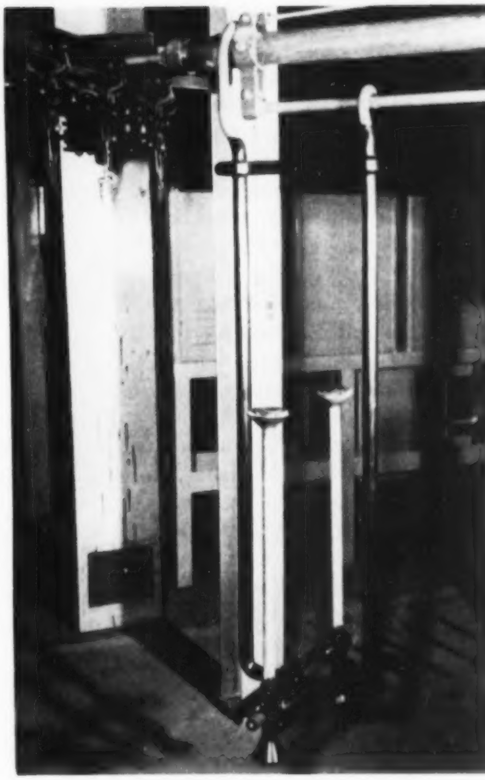


Fig. 5 – Conveyer Arm, Workholder, and the Two Inert Anodes. Anodes have double-cone construction at top

Fig. 6 – Method of Supporting Cartridge Case on Electrical Contacts of Workholder. The cone at base of workholder collects processing solution from manifolds located at the bottom of the processing tank

Various types of contact points which support the case and make electrical contact with the case through the workholder have been used. The most successful of these provides a tapered surface. The contacts are positioned so that the mouth of the case rests upon the tapered surface but will not slip down over the lower edge of the contact points, as shown in Fig 6.

An insulated locating pin projects from the top of the internal electrode and extends through the primer hole of the cartridge case to centralize the case with respect to the electrode, thereby promoting even current density to obtain uniform thickness of the zinc plate in the internal surfaces of the case.

The electrical requirements are supplied by Hanson-Van Winkle-Munning rectifiers and motor-generator sets. Rectifiers are used to supply current for the electrolytic cleaning operations and for application of the Anozinc. The rectifiers are the selenium type with variable voltage output from 0 to 15 volts, and a maximum current output of 4000 amp.

Current for the zinc plating operation is supplied by two motor-generator sets, one having an output of 12,500 amp. for the external plating circuit and the second a capacity of 7500 amp. for the internal circuit. Voltage output is variable from 2 to 10 volts.

In each of the above operations, two electrical circuits are required, one for processing the internal surface of the work, and the other for the external surfaces. When placed in position on the workholder, the steel cartridge case becomes one of the electrodes for both circuits.

The polarity of the case will depend upon the requirements of the operation. In the first electrolytic cleaning operation and in zinc plating, the work is cathodic. It is anodic in the second electrocleaner and Anozinc sections. The electrodes of opposite polarity to that of the case consist of the internal inert electrode of the workholder for the internal circuit, and flat mild steel plates suspended from busbars along the edge of the processing tanks for the external circuit. In the zinc plating tank, the external circuit electrodes consist of coiled-wire baskets suspended from the busbars and filled with cast balls of high-purity zinc.

A system of sprays is available when additional rinsing is required. These water sprays are located above the work so that as it is removed from the rinse tank external surfaces are washed down. Drying is speeded by air blow-off jets mounted on the side of the tank so that the air blast will remove the pool of water which collects on the heads of the cases as they are withdrawn from the rinse tank.

Disposal Systems—Considerable quantities of solutions containing acid, caustic, chromates and cyanides must be disposed of. Experience has shown that all solutions, other than those containing cyanides, can be safely collected and treated together.

Each processing tank is equipped with overflow weirs which maintain the maximum solution level approximately 3 in. below the top of the tank. Solution which flows over the weir is collected in a discharge line that empties directly into a brick-lined gutter. Floors adjacent to the processing area are sloped so that spillage of processing solutions may be easily flushed into the gutters.

The gutters discharge into 36x36-in. sand traps with Duriron sewer pipe outlets which feed into a plant-wide collection system for acid effluents. This in turn discharges into a collection well where the solution is processed automatically to neutralize any acid or alkali. The neutralized effluent is then pumped to large settling beds where dry precipitated solids are removed and the clear effluent is discharged into an adjacent river. The effluent must meet very stringent antipolution standards.

In the zinc plating section and adjacent cyanide solution filtering and draining areas, the floors are sloped to drain into a separate system of gutters and sumps. The cyanide-bearing solutions are discharged into a special sewer system to a cyanide destruction plant. Here the cyanide solutions are continuously and automatically treated with chlorine (in Wallace and Tiernan equipment) to completely destroy all cyanides. The cyanide-free effluent is discharged into sumps together with the neutralized acid effluent.

Conclusion—Individually, the chemical processes involved are neither unique nor complex, but collectively, the breakdown of any single chemical processing operation can be responsible for the failure of the unit as a whole. Furthermore, the mechanical accomplishment of these chemical processes is quite complicated and introduces a multitude of possible sources of breakdown or malfunction. Attention to concentrations and purity of processing solutions, operating temperatures and maintenance of the equipment is essential for the production of a satisfactory zinc plate as well as to obtain the maximum efficiency of the equipment.

New Numbering System for Wrought Aluminum Alloys

Adopted by the Aluminum Assoc., Oct. 1, 1954

Alloys are designated by a four-digit index system similar to the S.A.E. numbering system for steels. The first digit indicates the alloy group as shown in the tabulation alongside. The last two digits identify the particular alloy or indicate the aluminum purity. The second digit indicates alloy modifications or impurity limits.

Aluminum — In the 1xxx group for 99.00% min. aluminum the last two digits indicate the minimum aluminum percentage to the right of the decimal point. The second digit indicates modifications in impurity limits. If the second digit in the designation is zero, it indicates that there is no special control on individual impurities; while integers 1 through 9, assigned consecutively as needed, indicate special control of one or more individual impurities.

Thus, 1030 indicates 99.30% minimum aluminum without special control on individual impurities, and 1130, 1230, 1330 indicate the same purity with special control on one or more impurities. Likewise 1075, 1175, 1275 indicate 99.75% minimum aluminum; and 1097, 1197, 1297 indicate 99.97%.

Designations for Alloy Groups

Aluminum — 99.00% minimum and greater		1xxx
Major Alloying Element —	Copper	2xxx
	Manganese	3xxx
	Silicon	4xxx
	Magnesium	5xxx
	Magnesium and Silicon	6xxx
	Zinc	7xxx
	Other element	8xxx
Unused Series		9xxx

Aluminum Alloys — In the 2xxx through 8xxx alloy groups the last two digits have no special significance except to identify the alloy. Generally, these digits are the same as those formerly used to designate the same alloy. Thus, 2014 was formerly 14S, 3003 was 3S, and 7075 was 75S. For new alloys these last two digits are assigned consecutively beginning with xx01. The second digit in the designation indicates alloy modifications. If the second digit is zero, it indicates the original alloy; while integers 1 through 9, which are assigned consecutively, indicate alloy modifications. In the former system letters were used to designate alloy modifications. These were assigned consecutively beginning with A. Thus 17S is now 2017 and A17S is 2117, 18S is 2018 and B18S is 2218.

Experimental alloys are indicated by the prefix X. The prefix is dropped when the alloy becomes standard. During development, and before they are designated as experimental, new alloys are identified by serial numbers assigned by their originators. Use of the serial number is discontinued when the X number is assigned.

Temper Designations — The temper designation system in effect since Dec. 31, 1947, is being continued without change. The temper designation follows the alloy designation and is separated from it by a hyphen. Thus 3S-O is now 3003-O, Alclad 24S-T81 is Alclad 2024-T81, and 75S-T6 is 7075-T6.

Conversions, New to Old

New	Old	New	Old	New	Old
EC★	EC	2018	18S	5254	B54S
1030	AE1S	2024	24S	X5356	XC56S
1050	AD1S	2025	25S	5357	C57S, K157
1060	BD1S	2117	A17S	X5405	XD50S
1070	AC1S	X2214	XB14S	5652	F52S
1075	JC1S	2218	B18S	6003††	R306, K162
1080	BC1S	2225	B25S	6053	53S
1085	AB1S	X2316	XC16S	6061	61S
1090	FB1S	2618	F18S	6062	62S
1095	AA1S	3003	3S	6063	63S
1099	BA1S	3004	4S	6066	66S
1100	2S	X3005	XA5S	6151	A51S
1130†	R308	4032	32S	X6251	XB51S
1145	BE1S	4043	43S, K145	6253	B53S
1150	ED1S	4045	45S	X6453	XD53S
1160	CD1S, 99.6	4343	C43S, 44S, K143	6553	E53S
1175‡	99.75	X4543	XE43S	6951	J51S, K160
1180	CC1S, R998	5005	A50S, R305, K155	7070	70S
1187	EB1S, 99.87	5050	50S	7072	72S
1197	CA1S	5052	52S	7075	75S
1230★★	99.3	X5055	X55S	X7178	XA78S
1235	R995	5056	56S	7277	B77S
2011	11S	5083	LK183	8099	R399
2014	14S, R301 Core	5086	K186	8112	K112
2017	17S	5154	A54S	X8280	XB80S

★EC (the designation for electrical conductor metal) is not being changed since it is so firmly established in the electrical industry.

†No. 1 Reflector Sheet. ★★Cladding on Alclad 2024 (Alclad 24S).

‡Cladding on No. 2 Reflector Sheet. ††Cladding on Alclad 2014 (R301 and Alclad 14S).

Conversions, Old to New

Old	New	Old	New	Old	New
99.3★★	1230	17S	2017	56S	5056
99.6, CD1S	1160	A17S	2117	XC56S	X5356
99.75‡	1175	18S	2018	C57S, K157	5357
99.87, EB1S	1187	B18S	2218	61S	6061
EC★	EC	F18S	2618	62S	6062
AA1S	1095	24S	2024	63S	6063
BA1S	1099	25S	2025	66S	6066
CA1S	1197	B25S	2225	70S	7070
AB1S	1085	32S	4032	72S	7072
EB1S, 99.87	1187	43S, K145	4043	75S	7075
FB1S	1090	C43S, 44S, K143	4343	B77S	7277
AC1S	1070	XE43S	X4543	XA78S	X7178
BC1S	1080	44S, C43S, K143	4343	XB80S	X8280
CC1S, R998	1180	45S	4045	K112	8112
JC1S	1075	50S	5050	K143, C43S, 44S	4343
AD1S	1050	A50S, K155, R305	5005	K145, 43S	4043
BD1S	1060	XD50S	X5405	K155, A50S, R305	5005
CD1S, 99.6	1160	A51S	6151	K157, C57S	5357
ED1S	1150	XB51S	X6251	K160, J51S	6951
AE1S	1030	J51S, K160	6951	K162, R306††	6003
BE1S	1145	52S	5052	LK183	5083
2S	1100	F52S	5652	K186	5086
3S	3003	53S	6053	R301 Core, 14S	2014
4S	3004	B53S	6253	R305, K155, A50S	5005
XA5S	X3005	XD53S	X6453	R306, K162††	6003
11S	2011	E53S	6553	R308†	1130
14S, R301 Core	2014	A54S	5154	R399	8099
XB14S	X2214	B54S	5254	R995	1235
XC16S	X2316	X55S	X5055	R998, CC1S	1180

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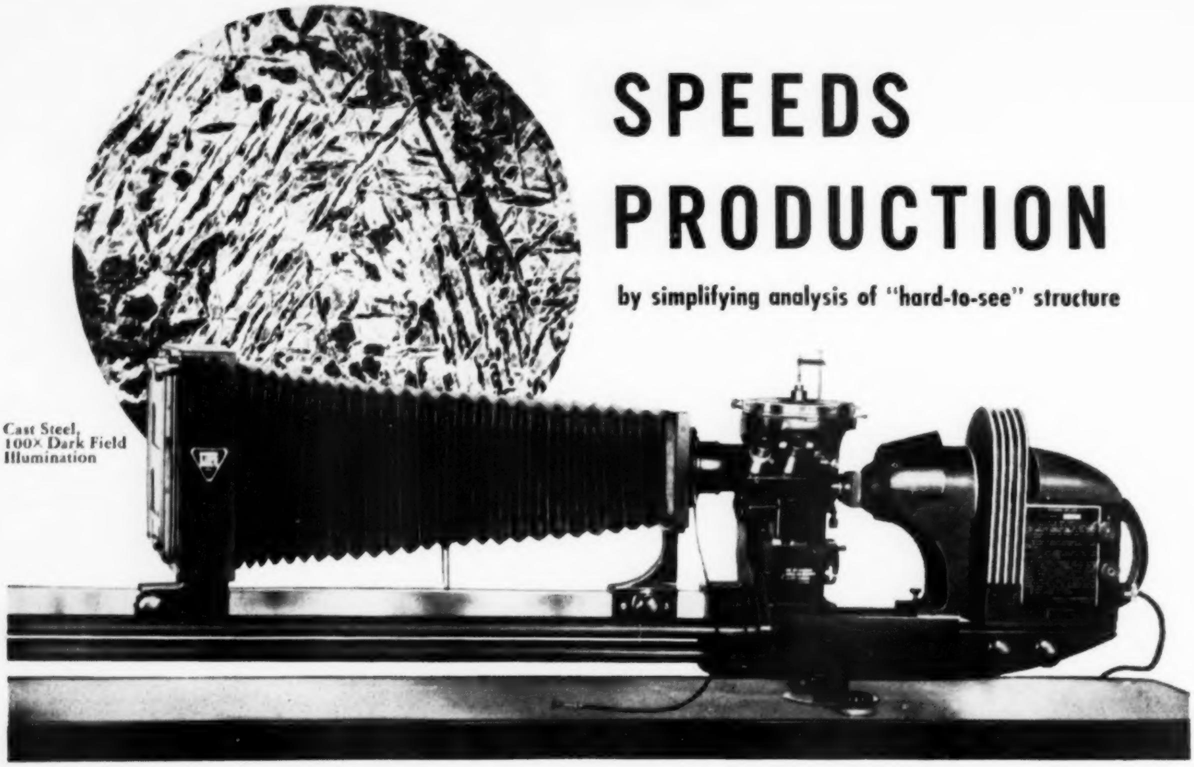

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SINCE 1853

METALLURGICAL EQUIPMENT

Aluminum in France

*Reported by T. L. FRITZLEN**

Meetings, exposition and plant visitations in a centenary celebration of Deville's production of aluminum metal, show that the French use of aluminum in automobiles (consuming one fifth the total output) is on a much greater scale than in America.

To COMMEMORATE the centenary of the world's first production of aluminum by Sainte-Claire Deville a scientific congress in Paris, June 14 to 19, was arranged by the Société Chimique de France and L'Aluminium Francais under the patronage of the president of the French Republic. The Société Chimique de France counted Deville as one of its presidents. A formal session was held at the Sorbonne wherein several addresses concerned Deville's scientific work and its industrial consequences.

Some 75 papers were presented at other sessions held at Maison de la Chimie ranging over a wide field: properties of the metal and its compounds, production, analytical procedures, alloying, surface protection, fabrication and applications. In these meetings the language difficulty – never met in metallurgical conferences here – was handled most efficiently. Summaries of the papers were presented in the author's language and simultaneously translated into French, German and English, with reception obtained by radio earphones tuned into the proper channel. Discussion was handled similarly. The proceedings will be published in full by the International Scientific Congress.

As stated, this gathering commemorated the 100th anniversary of an event which attracted no great amount of attention at the time. In 1851, Henri Sainte-Claire Deville, who at the age of 33 was head of the Chemistry School in Paris, interested Napoleon III and the French Academy of Science in his ideas for reducing the double salt of sodium-aluminum chloride by sodium amalgam. Three years later, in February and August, 1854, the results of his work were communicated to the Academy. His chemical method was developed in France with little delay, and the first aluminum of 96 to 97% purity was produced in Nanterre, a suburb of Paris. It cost £53 sterling per lb. (at least $1000.00 in 1954 dollars). The price per pound had dropped to £3, 12 shillings (about $70.00, 1954 dollars) in 1880, yet this high price clouded any prospects for the widespread application of aluminum in the industrial field, as predicted by the inventor.

Sainte-Claire Deville also presented a small ingot of pure aluminum to the French Academy of Science that same year (1854), which he had produced by igneous electrolysis. However, the lack of a cheap and abundant source of electrical power prevented the further development of his method. The construction of the first industrial electrical generator by Gramme in 1872, and the simultaneous discoveries of Hall and Heroult in 1886, resulted in the production of aluminum by electrolysis, the abandonment of the chemical method, and the fulfillment of Deville's early prophecy that aluminum could be developed into a useful metal.

Just how useful aluminum is, today, hardly needs to be specified to an audience of metallurgists. However, even a specialist could not help but be interested in the exposition held simultaneously with this commemoration by L'Aluminium Francais†. An outstanding feature

*Chief Metallurgist, Reynolds Metals Co., Richmond, Va.

†The Centre Technique de L'Aluminium in Paris serves to study and develop new uses for aluminum, to provide technical advice on the proper alloys to use and how to use them. As a technical center, it functions under the joint sales organization, L'Aluminium Francais, which in turn is supported by the two companies producing primary aluminum, Compagnie Pechiney and Société d'Electro-Chimie d'Ugine.

Photographs Courtesy of l'Aluminium Francais

Fig. 1 – The Aluminum Exposition Was Held in a Demountable Aluminum-Glass Building on the Left Bank of the Seine in Paris. Fig. 2 – Details of the Building Can Be Seen in the Interior Above – Also Informal and Attractive Displays of Work-a-Day Items. Fig. 3 (Upper Right) – Fifth-Scale Models of 100,000 and 50,000-Amp. Reduction Cells.

was the building itself which housed the exhibits – all aluminum and glass, 50 ft. wide by 492 ft. long. The main facade, facing the river, is 25 ft. high, and the rear wall is 18 ft. The slightly arched, self-supporting roof is made up of U-shaped girders 16½ ft. long, formed from 0.156-in. alloy plate, spliced at third points and fixed at ends into pressed fittings. Tubular posts were formed from similar sheet into two sections, spot welded together. Aluminum roofing sheets covered the girders and were hooked onto them. Side plates and panels of aluminum sheet were fixed by clips fitted into grooves in the facade posts. Figure 1 shows the outside of this exposition building and the exterior construction. Note how the fact that the site is a stone-paved quay does not exclude a bed of glowing flowers. An idea of the interior construction and display arrangements can be had from Fig. 2. Semi-finished products, finished articles and fabricating operations were on exhibit. Figure 3 shows fifth-scale models of vertical-pin 50,000 and 100,000-amp. cells for electrolytic reduction. Operations such as melting, die casting, induction heating, impact extrusion, foil printing, anodizing, welding, sonic testing and spectrographic analysis were performed in working exhibits, even to a 1000-ton Loewy press extruding an aluminum shape.

This aluminum exhibition disclosed considerably more application of aluminum to the automotive industry, proportionally, than in the United States. Between 20 and 25% of France's total consumption of aluminum goes into the automotive industry; this in contrast to an estimated 5% or less to automotive uses in the United States. The high cost of gasoline in France makes the weight of the automobile an important economic factor. For example, the Dyna-Panhard, designed to use aluminum to the greatest extent, weighs 1323 lb. as against 2205 lb. for competitive cars of similar size. The Dyna has a two-cylinder, air-cooled engine said to be capable of a maximum speed of 80 miles per hr. with full load, an acceleration from stop to 50 miles per hr. in 10 sec., and an average gas consumption of 40 miles per gal. The writer toured southeastern France in a new Dyna-Panhard, and the way it performed through village and countryside convinced him that the claims for maximum speed and acceleration are easily met.

During this trip a visit was made to the Issoire Works of Cegedur (aluminum rolling mill) and Compagnie Pechiney works at Saint-Jean de Maurienne (reduction plants) in central and southeastern France, in company with about half of the 476 registrants of the Congress. Outstanding developments observed in these visitations were the operation of an induction furnace for continuously heat treating aluminum alloy strip (described in *Metal Progress* for October 1951) and the vertical-pin 100,000-amp. cells of Söderberg design for aluminum reduction.

Henri Sainte-Claire Deville was a prophet when he said, in 1854, that aluminum could be developed into a useful metal.

Induction Surface Hardening of Ductile Iron

*By JOSEPH F. LIBSCH and JOSEPH C. DANKO**

Ductile or nodular cast iron, heat treated by quench and temper or isothermally to a structure containing considerable combined carbon, can be case hardened by rapid induction or flame heating to about C-57, with case depths somewhat greater than for steel.

RECENT publications on ductile iron have reported mechanical properties which offer many interesting engineering possibilities. Among these possibilities is that it may be surface hardened. A hard surface supported by a ductile core of good strength may provide a unique combination of properties for iron castings. While considerable variation in the mechanical properties in the as-cast state may result from changes in analysis and production techniques, maximum variation is achieved by heat treatment. The ductility may be increased progressively by either of two methods – *(a)* heating the casting to the 1600 to 1700° F. range followed by isothermal transformation at 1100 to 1300° F., or *(b)* rapid cooling from 1650 to 1700 and tempering at 1100 to 1300° F. The increase in ductility with increased time and temperature of isothermal transformation or of tempering is basically related to a progressive increase in the ratio of ferrite to pearlite in the microstructure, and is accompanied by a continuous decrease in yield and tensile strength. It is thus possible to select various combinations of mechanical properties deemed desirable as core properties in surface hardened sections.

Case hardening of cast iron requires a *rapid* heating of the surface with such techniques as induction and flame heating so very little heat penetrates to the interior. Unfortunately, rapid heating gives a minimum of time for carbon to diffuse and form reasonably homogeneous austenite prior to quenching. Successful surface hardening therefore depends upon the structure *prior* to case hardening.

Suitable prior structures of ductile iron consist of ferrite, secondary carbide (pearlite or other fine mixtures of ferrite and carbide) and graphite spheroids. However, the distribution of these microconstituents may vary extensively, depending upon prior heat treatment – quenching and tempering or isothermal transformation. The ultimate structure for either extended tempering or long isothermal treatment is a fully "ferritized" structure consisting only of ferrite grains and spheroidal graphite (spherulites).

In practice, castings for isothermal treatment are heated to 1600 to 1700° F. for 1 to 2 hr., then cooled rapidly to a temperature between 1100 and 1350° F. and held for a time which depends upon the time-temperature-transformation curve and the rate of ferrite formation. Figure 1 gives TTT-curves for two heats of ductile iron principally varying in their silicon content, Heat N (2.98% Si) and Heat K (1.87% Si). Complete analyses are given in Table I.

The wide variation in possible microstructures is illustrated by three insets selected from a more complete presentation by E. P. Rowady, W. J.

*Dr. Libsch is professor of metallurgy and Mr. Danko is research fellow and instructor at Lehigh University, Bethlehem, Pa. Dr. Libsch is also consulting metallurgist to Lepel High Frequency Laboratories of New York City. The International Nickel Co. sponsored the work described, so the term for the material preferred by that company – ductile iron – is used in this article.

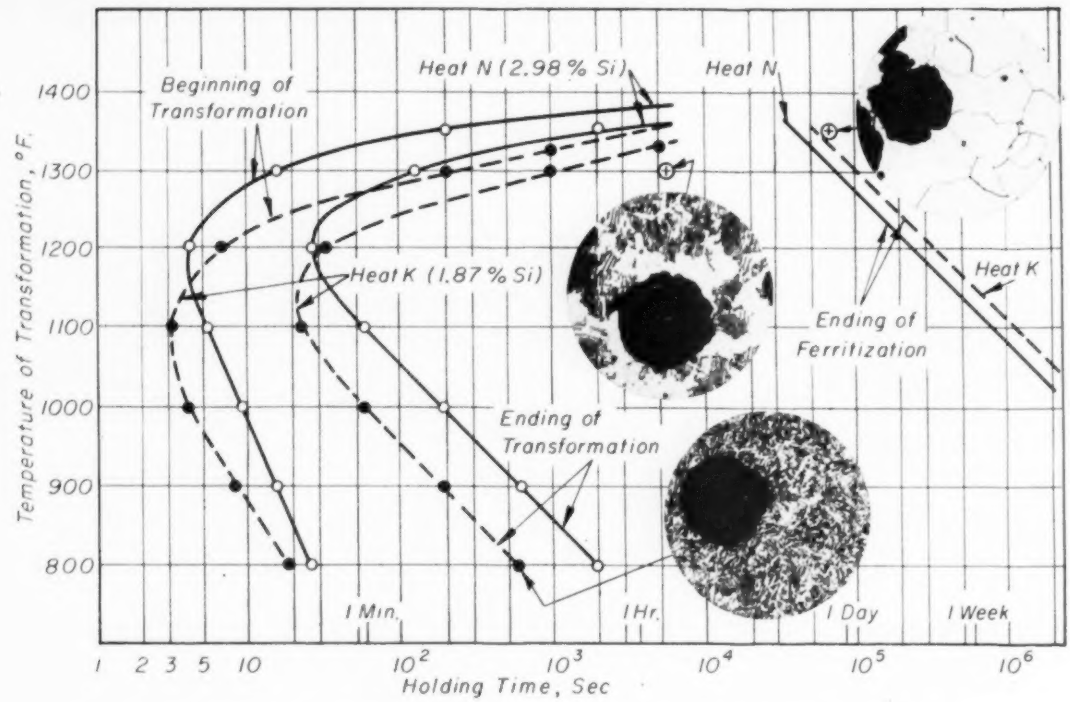


Fig. 1 – TTT-Curves for Heat N (2.98% Si) and Heat K (1.87% Si), Both Austenitized at 1600° F. Partially ferritized structure of Heat K (1300° F., 1.5 hr.); totally ferritized structure of Heat N (1350° F., 16.5 hr.); acicular structure of Heat K (800° F., 10 min.) at 200 ×

Murphy and J. F. Libsch before the 1953 meeting of the American Foundrymen's Society. The products of transformation at 1300° F. consist of coarse pearlite, ferrite and spheroidal graphite. Increased time at elevated temperature causes gradual decomposition of the secondary carbide to produce a completely ferritized structure. As the temperature of isothermal transformation decreases, the pearlite spacing becomes progressively smaller and the time for ferritization rapidly increases. The metallic matrix that forms below the nose of the isothermal transformation diagram (below 1000° F.) is predominantly acicular in nature.

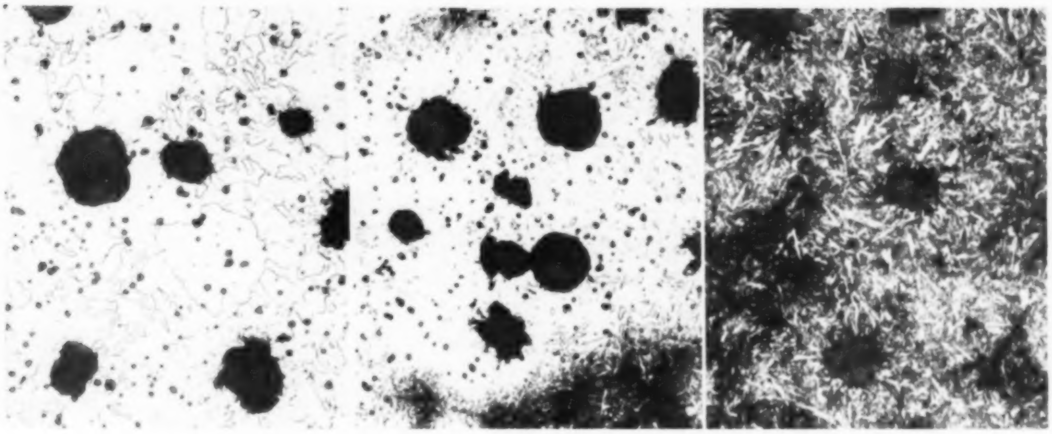
Table I – Composition of Heats Studied

Element	Heat K	Heat L	Heat M	Heat N
Total carbon	3.42%	3.24	3.47	3.49
Silicon	1.87	2.06	3.10	2.98
Manganese	0.32	0.73	0.78	0.34
Nickel	0.75	0.63	0.83	0.83
Phosphorus	0.034	0.020	0.034	0.034
Sulphur	0.01	0.016	0.01	0.01
Magnesium	0.076	0.063	0.062	0.056

The mechanical properties of isothermally transformed structures vary in a continuous manner with temperature and time, the range of properties varying from 134,000 to 52,600 psi. for tensile strength, 4 to 20.6% elongation, and 26 to 70 ft-lb. for impact resistance (unnotched Charpy) in Heat K, a low-silicon (1.87%) low-manganese (0.32%) heat.

Quenched and tempered castings are oil quenched from 1600 to 1700° F. Tempering is in the 1100 to 1300 range for one or more hours. The influence of tempering temperature upon structure for Heat K is shown in Fig. 2. Note the finely dispersed acicular ferrite-carbide aggregate at 1100° F. (Fig. 2, left), the partially ferritized structure at 1200° F. (Fig. 2, center) and finally a structure consisting of equiaxed grains of ferrite plus large primary and tiny secondary graphite spheroids at 1300° F. (Fig. 2, right). The secondary graphite is typical of quenched structures tempered at 1100° F. or above.

The mechanical properties of the quenched and tempered structures generally vary in a continuous manner with tempering tempera-



1100° F. 1200° F. 1300° F.

Fig. 2 — Heat K, Oil Quenched From 1650 and Tempered 2 Hr. at Temperatures Shown. Picral-nital etch. 250 ×

ture as illustrated by Fig. 3 for Heat N. The discontinuity in the tensile strength curve shown at tempering temperatures of 1100°, typical of all heats studied, seems to be associated with the change from acicular to equiaxed ferrite and the appearance of secondary graphite.

It thus appears that quenched and tempered structures also provide a wide range of properties for selection of core properties in a case hardened section.

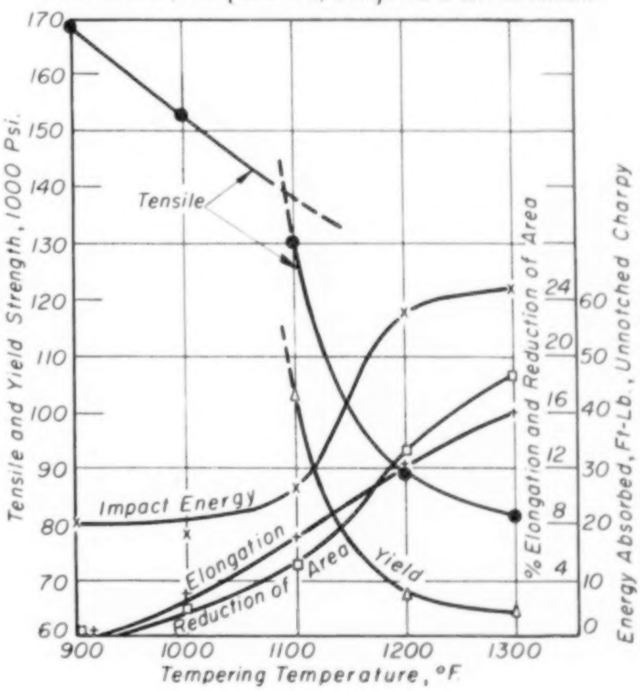
Hardening Response

The martensitic hardness of unquenched engineering steels and cast iron depends upon the carbon in solution in the austenite at the time of quenching. It has been well established that iron carbide has time to dissolve readily in austenite during conventional induction hardening cycles, but that graphite enters solution but slowly. However, both dissolve faster as temperature goes up. Thus it might be expected that the combined carbon (carbide content) would play a major role, and that graphitic carbon might become important only as either the hardening temperature or soaking time was increased.

This influence of prior structure upon the induction hardening characteristics of ductile iron is well illustrated in the three diagrams of Fig. 4. The test pieces were oil quenched from 1650° F. and tempered for 2 hr. at 1100, 1200 and 1300° F. respectively. Microstructures were similar to those shown in Fig. 2. It is apparent that the surface hardness after heating to 1600° F. and quenching in water (top diagram of Fig. 4) varies significantly with both prior structure and time at 1600° F.

For conditions leading to a minimum case depth the results presented for zero time are

Fig. 3 — Mechanical Properties of Heat N, Austenitized 1 Hr. at 1650, Oil Quenched, Tempered 2 Hr. as Shown



most significant, for they represent quenching immediately upon reaching 1600° F. It took only 3 or 4 sec. to reach temperature. As the amount of combined carbon (carbide in the prior structure) decreases, the response to induction heating decreases. Only the structure formed by tempering at 1100° F. would provide reasonable surface hardness by heating to 1600° F. It is interesting to note, however, that even the material essentially ferritized (1300° F., 2 hr.) may develop satisfactory hardness in the remarkably short period of 30 sec.

The influence of prior structure can be largely overcome by increasing the induction hardening temperature as is shown in the middle diagram of Fig. 4. Apparently raising the hardening temperature to 1700° F. has provided successful response for all prior structures.

However, *excessive* hardening temperatures not only increase the case depth but may retain substantial amounts of austenite in the quenched structure. Thus, induction heating to 1800° F. (bottom diagram of Fig. 4) causes a progressive decrease in hardness with time at temperature. Subzero cooling experiments demonstrate that most of this loss is associated with retained austenite in the hardened structure. High-manganese heats (0.78%) are particularly affected by high hardening temperatures.

Although the above data pertain to quenched and tempered castings, isothermally transformed structures behave similarly. As the amount of ferrite and the coarseness of the pearlite in the prior structure increase, the response to induction heating decreases.

Selection of the prior microstructure for induction surface hardening should then be guided primarily by the properties desired in the core. Where the ductility desired does not exceed 3 to 6% elongation, the prior structure provides almost immediate response to induction surface hardening, and little attention need be accorded the hardening cycle. When intermediate ductility is required – about 8 to 12% elongation – the prior structure becomes important and the induction hardening temperature and case depth may have to be increased to provide suitable response. Completely ferritized structures with maximum ductility (18 to 22% elongation) are generally unsuitable for surface hardening.

Another factor in the selection of prior structure, either quenched and tempered or isothermally transformed, is the ease of processing in an individual plant. Structures from either program respond suitably if heat treated to the same

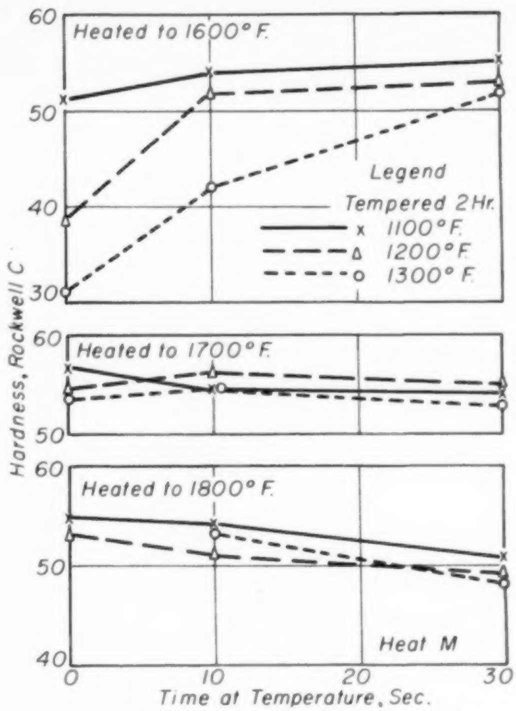


Fig. 4 – Hardness of Samples of Ductile Iron (Heat M) Inductively Heated to 1600, 1700 or 1800° F. for Times Indicated and Then Water Quenched. Prior structures of wide variety (Fig. 2) will satisfactorily harden when heated to 1700° F.

mechanical properties. Since castings frequently have a large amount of combined carbon as cast, they may generally be successfully induction hardened from 1700° F. without preliminary heat treatment if the core properties are suitable. This temperature appears generally most suitable to minimize the influence of prior structure and to avoid retention of austenite. Where minimum case depths are required, a lower hardening temperature and a microstructure containing a minimum of massive ferrite are desirable.

Influence of Composition

Several heats of ductile iron varying principally in manganese and silicon were studied to determine the influence of composition on induction surface hardening (see Table I).

Perhaps the most prominent influence of composition is upon microstructure and mechanical properties before induction heating. The significant influence of silicon in raising the curves representing beginning and ending of isothermal transformation and decreasing the time required

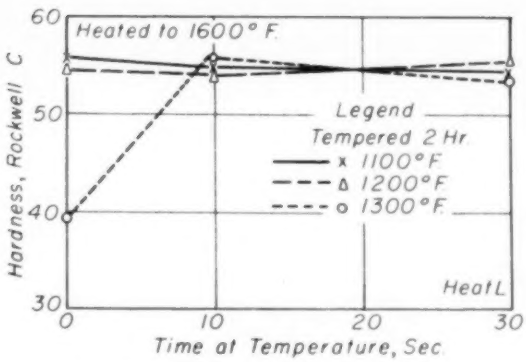


Fig. 5 – Hardness of Sample of Low-Silicon Heat L, Quenched and Tempered, Then Inductively Heated to 1600° F. and Water Quenched. Compare with top diagram of Fig. 4 for effect of silicon

for complete ferritization is illustrated by comparing Heat N with 2.98% Si and Heat K with 1.87% Si as shown in Fig. 1. (In quenched structures silicon promotes more rapid ferritization on tempering.)

An increase in manganese (to 0.78%) appears to extend the time required for the beginning and ending of austenite transformation and for complete ferritization, particularly at temperatures below 1200° F. Thus for equivalent heat treating procedures one might expect greater amounts of combined carbon with high-manganese heats. However, essentially equivalent structures may be attained in all the heats studied, provided adjustments are made in the heat treatments.

The mechanical properties are likewise influenced by composition, partly as a direct alloying influence and partly as an indirect influence upon prior structure. In general, silicon appears to provide a better balance of mechanical properties – that is, the silicon steels have higher strength for similar ductility.

Response to Induction Heating – Silicon appears to decrease somewhat response to induction hardening in both isothermally transformed and in quenched and tempered prior structures. This appears to be a direct effect (perhaps an influence upon carbon diffusion) and an indirect effect (less combined carbon in the prior structure for a uniform heat treatment). The influence of silicon can be inferred by comparing the top diagram of Fig. 4 (Heat M; 3.10% Si, 0.78% Mn) and Fig. 5 (Heat L; 2.06% Si, 0.73% Mn).

Since the variation in prior structure produced by silicon can be largely overcome by a change in heat treatment, and since higher induction hardening temperatures minimize the influence of prior structure, the slower response of high-silicon ductile irons to induction heating is not a major disadvantage.

Manganese appears to increase the tendency for retained austenite in the hardened structure, though this may also occur in low-manganese heats. Since manganese tends to stabilize austenite, this may be expected. Thus high-manganese heats may be more sensitive to excessive induction hardening temperatures.

Selection of Composition – The most outstanding observation concerning the influence of composition, within the limits studied, appears to be the relative insensitivity of successful induction heating response to composition. Variations in composition can be accommodated either by moderate changes in preliminary heat treatment or by using higher induction hardening temperatures.

However, since silicon provides a somewhat better balance of core properties and decreases the time required for partial ferritization, it appears that castings within the range of 3.25 to 3.50% total carbon, 2.5 to 2.75 silicon, 0.35 to 0.50 manganese, 0.65 to 0.85 nickel, 0.030 to 0.035 phosphorus and 0.01% sulphur would be preferred. Such analyses also respond excellently to induction surface hardening. Where castings have been made without consideration for surface hardening, modifications in initial heat treatment to control prior structure and selection of correct hardening temperature will result in successful surface hardening.

Control of Case Depth

The preceding discussion provides little data concerning either the properties of the hardened case or the case depths to be expected.

Case depth depends not only upon the metallurgical variables such as prior structure, composition, and hardening temperature, but also upon the characteristics of the heating apparatus, as well as the magnetic, thermal, and electrical characteristics of the ductile iron. The power available in the high-frequency converter and the frequency may both have an important influence. Thus, minimum case depths are produced with converters which operate at high frequency and have sufficient power available to bring the surface to the hardening temperature in a minimum of time so as to minimize conduction of heat to the interior. This, in turn, will depend upon the design of the induction heating

coil, the quenching fixture and the possible use of progressive localized hardening.

Furthermore, since the effective current penetration is directly proportional to the square root of the electrical resistivity of the iron and inversely proportional to the square root of its magnetic permeability, it is apparent that composition may influence the case depth. Increased silicon content, for example, appears to increase the case depths somewhat.

There is no limitation on *maximum* case depth – except perhaps the hardenability (in very large sections). However, there is a definite *minimum*, both as a result of the induction heating equipment and the electrical and metallurgical characteristics of the iron. While the minimum practical case depth in induction hardened steels is approximately 0.020 in., it may be considerably deeper in a ductile iron of appreciable ductility. The deeper case results from the higher hardening temperature required to put sufficient carbon in solution prior to quenching. Where minimum core ductility is required, the practical minimum case depth may approach that for steel.

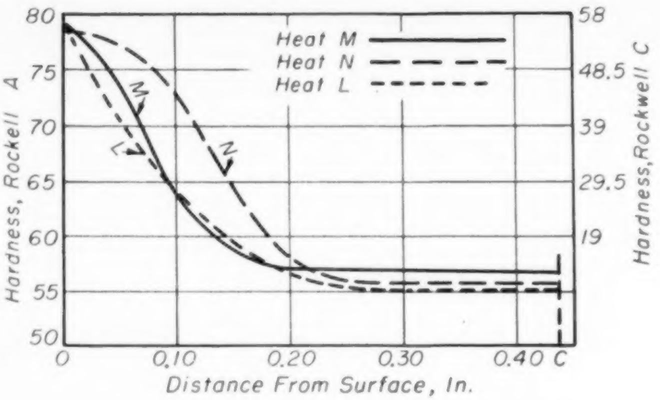


Fig. 7 – Depth-Hardness Curves as They Are Affected by Composition. (See Table I.) Conditions same as in Fig. 6 except all samples were tempered 2 hr. at 1200° F. prior to surface hardening

Case Characteristics – Figure 6 illustrates depth-hardness curves obtained on 0.875-in. rounds with various quenched-and-tempered prior structures; Fig. 7 various compositions. These rounds were case hardened using a 30-kw. spark-gap converter operating at a frequency of 300,000 cycles per sec. All were heated to a surface temperature of 1700° F. in a rotating fixture and immediately spray quenched in water.

In all instances the surface hardness measured Rockwell A-78 to 80, equivalent to C-54 to 58.

Although the prior microstructure has little influence on the surface hardness, it does upon the hardness gradient (Fig. 6). There appears to be a greater depth of high hardness and a steeper hardness gradient between the core and case as the combined carbon in the structure decreases. The "case depth", represented as the distance to a hardness of A-70, also increases somewhat as the prior tempering temperature increases. We believe that these variations are associated with significant variations in the electrical, thermal and, perhaps, magnetic characteristics of the ductile iron as its structure changes. It is also believed that the distribution of silicon in the structure may be a primary influence.

The depth-hardness curves of Fig. 6 are for a heat of ductile iron (Heat N) of recommended composition and hardening temperature. Its mechanical properties are given in Table II. These properties are to be expected in the core of the case hardened sections.

Composition (within the limits

Fig. 6 – Effect of Prior Structure on Depth-Hardness Curves for Case Hardened Rounds, 0.875 in. Diameter, of Heat N. No dwell of current – that is, surface was spray quenched immediately upon reaching 1700° F. Prior treatment: oil quenched from 1650° F., tempered for 2 hr. as indicated

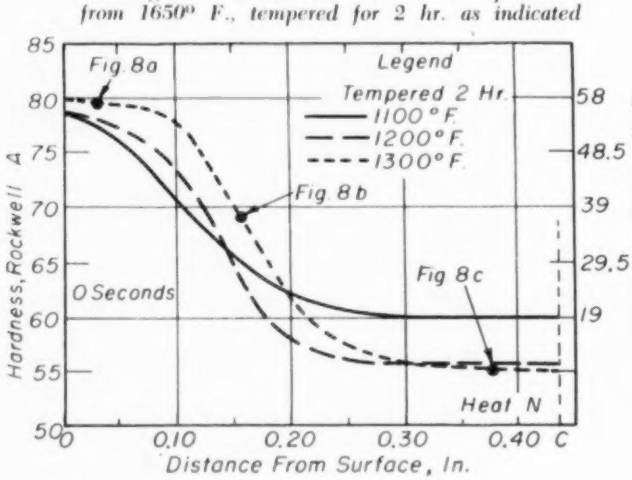


Table II – Mechanical Properties of Samples of Fig. 6 and 7
(All pieces oil quenched from 1650° F., tempered 2 hr. as noted)

Heat	Tempering Temperature	Tensile Strength	Yield Strength	Elongation (a)	Reduction of Area	Impact Resistance (b)
		Influence of Prior Structure (Fig. 6)				
N	1100° F.	130,000	103,000	7%	5%	26
N	1200	89,000	68,000	12	13	58
N	1300	81,000	64,000	16	18.5	62
		Influence of Composition (Fig. 7)				
N	1200	89,000	68,000	12	13	58
M	1200	87,000	67,500	10	10	40
L	1200	99,000	87,000	7	7.5	35

(*a*) A.S.T.M. Standard 0.250-in. diameter, 1-in. gage length tensile bars.
(*b*) Unnotched Charpy bars, broken at room temperature.

studied) appears to have a minor influence, although Heat N with low manganese maintains a higher hardness to a deeper level. (See Fig. 7.)

The microstructure of a surface hardened section is shown in Fig. 8. Uniform martensite with graphite spheroids exists for some depth from the surface, after which a mixture of martensite, ferrite and graphite spheroids with ever-increasing amounts of ferrite gradually merges into the core structure.

Summary

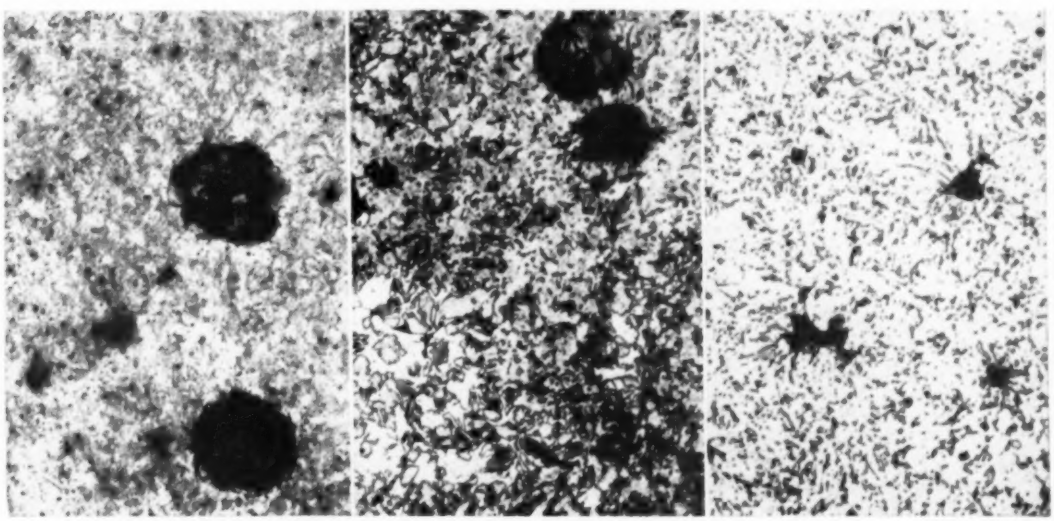
Ductile iron can be surface hardened by induction heating to provide a unique combination of properties. High case hardness is possible with a wide variation of core properties. The operation does not appear to require unduly precise control, and while prior structure and composition have an influence, the hardening temperature can be adjusted for successful surface hardening in all structures except those that are substantially ferritized.

Optimum surface hardening may be expected with material containing 3.25 to 3.5 total carbon, 2.5 to 2.75 silicon, 0.35 to 0.50 manganese, 0.65 to 0.85 nickel, 0.03 to 0.035 phosphorus and 0.01% sulphur, surface hardened at 1700° F. However, the composition does not need to be closely adjusted. Prior microstructures containing a maximum amount of combined carbon, widely distributed, will produce minimum case depths, while microstructures containing large amounts of ferrite are responsible for deeper cases.

While tests on production pieces are required to determine the ultimate usefulness of surface hardened ductile iron parts, it is believed that the unique combination of properties provided offers many possibilities in the design of cast parts for engineering applications.

Fig. 8 – Typical Microstructures of Surface Hardened Ductile Iron (See Fig. 6). Picral-nital etch; 250 ×

Edge *Transition* *Center*



Sigma Phase–a Review

*By ADOLPH J. LENA**

Sigma can be identified by microscopic methods and by X-ray analysis of the bulk material or the concentrated phase. Sigma occurs in many binary and ternary systems, some of which compose the high-temperature alloys.

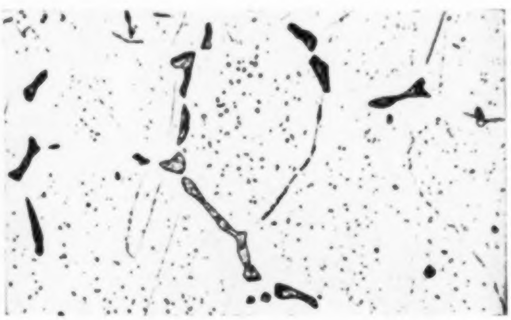
The two preceding articles in this three-part series described the compositional limits and effects of sigma formation on stainless steels; this final part is devoted to the identification of sigma in stainless steels, as well as to some of the theoretical aspects of its formation in other binary and ternary alloys and its crystal structure.

The microscopic identification of phases in stainless steels which contain sigma is often very difficult, particularly if the sigma particles are small, because of the similarity in etching characteristics of sigma and carbide. The presence of both constituents in the microstructure is a general condition in sigma-containing steels since carbides form more rapidly than sigma in the same temperature range. Further complications arise in some austenitic steels when small amounts of ferrite are present.

Etchants commonly used for stainless steels have been classified into three broad groups: *(a)* acid reagents of the immersion type, *(b)* electrolytic etchants, *(c)* alkaline ferricyanide reagents. The acid types (picric and hydrochloric acid in alcohol is common) usually attack austenite and leave carbides, sigma and ferrite in relief without differentiating among them. The electrolytic etchants, in general, attack sigma and carbides vigorously but the austenite relatively slowly so that it is possible to identify the ferrite phase by difference. In some steels, certain electrolytic etchants attack either carbide or sigma more rapidly and it is often possible to distinguish between the two in this manner. A detailed study of the common etchants and their effects on these phases has been made by E. J. Dulis and G. V. Smith ("Symposium on the Nature, Occurrence and Effects of Sigma Phase", A.S.T.M., 1950), who found that no one etchant would provide a general differentiation of phases in all types of stainless steels.

The alkaline ferricyanide etchants have been used quite widely for identification of phases in steels where sigma is present. These are the Murakami and modified Murakami solutions and may be used either cold or boiling. They are staining etchants and as such are, in general, unsatisfactory. If used hot, the carbides are usually stained a dark brown, sigma assumes a series of opalescent colors, ferrite turns a light tan and the austenite remains unaffected. Such solutions work well on ferritic alloys, but not on austenitic alloys, because on the latter the colors of staining are not consistent. However, the staining solutions are useful for austenitic steels when employed in conjunction with other etchants. An

Fig. 1 – Type 310 Etched in Aqua Regia With Sigma Attacked and Carbides in Relief. Steel was annealed before aging. 1000 ×



*Associate Director of Research, Allegheny Ludlum Steel Corp., Brackenridge, Pa.

Editor's Note – This paper is a review of the most significant investigations made to date of the formation of sigma and of its effect on the properties of alloys. (See *Metal Progress* for July and August for the first and second parts of this article.) To preserve its continuity, many of the credits and the complete bibliography submitted with the paper have been deleted.

example of this technique is the etching sequence recommended by Dulis and Smith:

1. Picric and hydrochloric acids in alcohol to reveal all constituents.

2. Alkaline ferricyanide at room temperature to stain carbides and leave sigma and ferrite unattacked.

3. Chromic acid electrolytically to severely attack carbides and sigma, thus differentiating either from ferrite.

Since the effect of most etchants varies so widely with composition, it appears unlikely that any single reagent will give positive identification of carbides and sigma in all types of stainless steels. There are a number of etchants which have a selective effect on carbides or sigma in a particular type of steel and can be applied with reliability when the type of steel being examined is known. Etchants of this kind are listed in Table 1, and examples of some of their effects are shown in Fig. 1 to 4. It will be noted that the electrolytic chromic acid which attacks sigma in Type 310 and leaves carbide in relief has the opposite effect on the chromium-manganese austenitic stainless steel. In molybdenum-bearing 18-8 steels (Types 316 and 317), the carbides are attacked faster than sigma when etched electrolytically in sodium cyanide. Overetching must be avoided in order to differentiate between the carbides and sigma, and this can be done by etching for shorter time than is normal to show carbides in stainless steels, or by reducing the strength of solution from 10 to 5%. Further aids to the identification of phases are a knowledge of previous heat treatment and the use of a magnetic test for positive differentiation between ferrite and sigma.

Table I – Etching Reagents for Differentiating Sigma From Carbides

Type	Etchant	Etching Effects	
		Carbides	Sigma
310, 314, 321	Aqua regia	In relief	Attacked and recessed
310, 314, 321	Cupric sulphate	In relief	Attacked and recessed
310, 314, 321, 347	Ferric chloride and hydrochloric acid in water	In relief	Attacked and recessed
316, 317	Electrolytic sodium cyanide	Attacked	In relief
310	Electrolytic chromic acid	In relief	Attacked
15% Cr, 17% Mn	Electrolytic chromic acid	Attacked	In relief

Another etching sequence recommended by J. J. Gilman (*Transactions* ⊕, Vol. 44, 1952, p. 556) takes advantage of the fact that strong hydroxide solutions used electrolytically color the sigma phase more rapidly than the carbides if the solutions are concentrated, and have the opposite effect if they are dilute:

1. Picric acid and hydrochloric acid (Vilella's etch) to outline the general structure.

2. Electrolytic 10N potassium hydroxide just long enough to color the sigma only and not the carbides.

3. Electrolytic concentrated ammonium hydroxide to color the carbides.

This technique has been applied to the identification of phases in Types 302, 316, 321, 310 and 314 and a cast steel containing 0.40% C, 1.10% Si, 6.4% Ni and 24.0% Cr. The same method has been used in our laboratory on Type 310 with results far superior to those of any other etching tech-

Fig. 2 – Type 310 Etched in Electrolytic 10% Chromic Acid; Sigma Attacked and Carbides in Relief. Steel was cold rolled before aging. 1000 ×

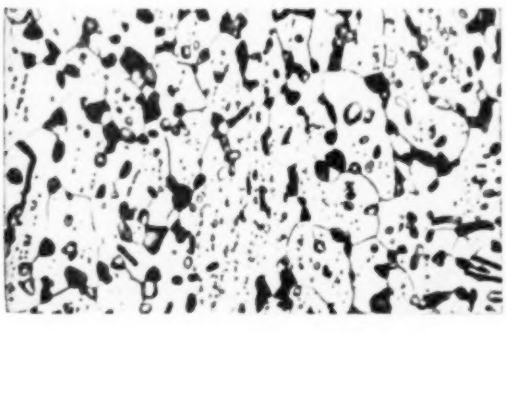
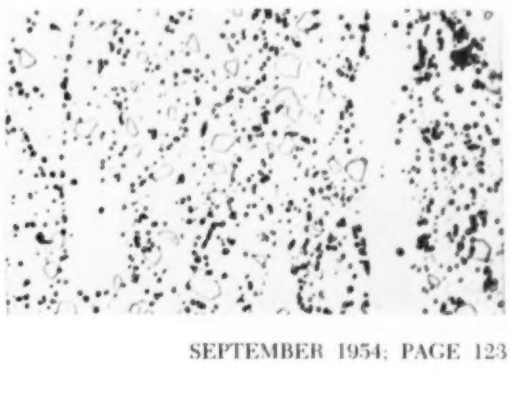


Fig. 3 – Electrolytic Etching of Austenitic Cr-Mn Steel in 10% Chromic Acid Attacks Carbides and Leaves Sigma in Relief. 1000×



nique for distinguishing between sigma and carbides. Close control of the voltage and time is required to avoid overetching.

Heat tinting appears to have some merit for the identification of sigma, but this method has not been fully exploited. Heat tinting has been found to cause austenite to turn blue-green and the sigma orange while carbides remain white. However, this method does not differentiate between ferrite and sigma since both have the same orange color. An electrolytic chromic acid etch followed by staining in an alkaline permanganate solution has been recommended for the identification of sigma in chromium-base Fe-Cr-Mo alloys. Other special techniques for specific alloys are mentioned in many of papers that have been written on this subject.

Positive identification of sigma can be made by X-ray analysis from its characteristic diffraction pattern which is greatly different from that of any other phase found in stainless steels. The actual line spacings vary somewhat with composition; in the ternary iron-chromium-molybdenum system, where the sigma region extends to at least 40% molybdenum, both a and c vary linearly with molybdenum content, and the c:a ratio is constant.

If the sigma is present in amounts too small to be detected by X-ray analysis of bulk specimens, suitable means must be taken to concentrate the sigma. The method devised by W. J. Barnett and A. R. Troiano (*Metal Progress*, Vol. 53, March 1948, p. 366) is to electrolytically etch in a 10% ferric chloride solution to concentrate the sigma on the surface by selective dissolution of the matrix. Etching can be prolonged to dissolve the entire specimen. The extraction is made in a cell such as shown in Fig. 5. The residues obtained from this extraction are filtered, washed, dried and analyzed by X-ray methods. Very small amounts of sigma can be detected with this method. Other techniques reported for the concentration of sigma include the chemical attack of the matrix by a hydrochloric acid-picric acid solution to concentrate sigma in ferritic alloys described by R. M. Fisher, E. J. Dulis and K. G. Carroll (*Transactions*, American Institute of Mining and Metallurgical Engineers, Vol. 197, 1953) while T. P. Hoar and K. W. J. Bowen (*Transactions*, Vol. 45, 1953) have provided quantitative data on the chemical composition of sigma and the austenite in equilibrium with it in an 18-8-3-1 Cr-Ni-Mo-Ti steel by selectively dissolving these constituents by electrolysis in hydrochloric acid and sulphuric acid solutions.

Sigma in Other Binary and Ternary Alloys

Considerable interest has arisen in recent years in the discovery of phases with the sigma structure in binary and ternary alloys of transition metals other than iron-chromium and iron-chromium-nickel. The binary and ternary systems in which sigma has been discovered are listed in Table II. Sigma phase structures of the binary alloys that contain a heavy element (either tungsten or molybdenum) are stable only at high temperatures and decompose on cooling. All of the other sigma structures are found in binary systems of the first long period and are stable at low temperatures.

The composition ranges of sigma phase structures have been determined for a limited number

Fig. 4 – Type 316 Etched Electrolytically in Sodium Cyanide: (Left) Carbides Attacked and Sigma Stained and in Relief; (Right) Sigma Stained and in Relief; No Carbides in This Steel. Both at 1000 ×

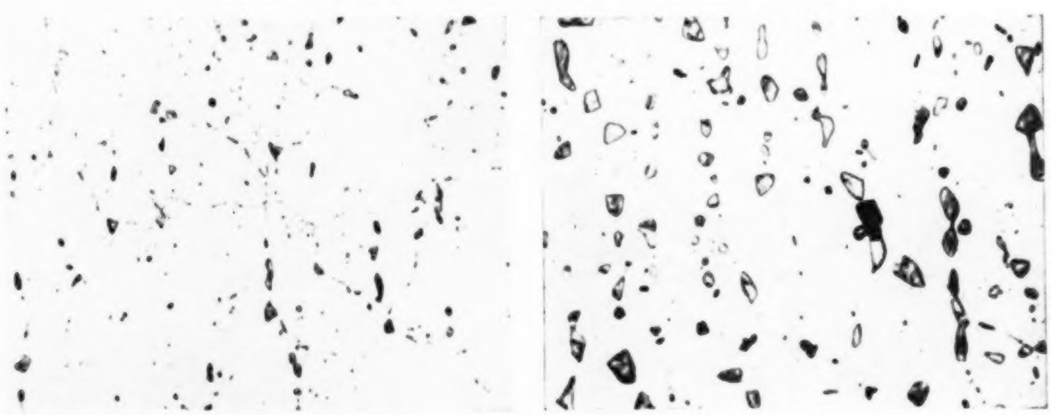


Table II – Sigma-Containing Alloys

Binary Systems	Reference*
Iron-Chromium	1
Cobalt-Chromium	2, 3, 4
Iron-Vanadium	5
Nickel-Vanadium	6, 7
Chromium-Manganese	6, 8, 9
Vanadium-Manganese	6
Vanadium-Cobalt	6, 7
Iron-Molybdenum	10
Molybdenum-Manganese	11, 12
Cobalt-Molybdenum	13
Cobalt-Tungsten	13
Iron-Tungsten	13
Ternary Systems	
Iron-Chromium-Molybdenum	14, 15, 16
Chromium-Cobalt-Iron	4, 17
Chromiun-Cobalt-Nickel	4, 17
Iron-Chromium-Molybdenum	18
Iron-Chromium-Tungsten	18
Chromium-Cobalt-Molybdenum	17
Chromium-Nickel-Molybdenum	17
Iron-Chromium-Vanadium	19
Iron-Chromium-Cobalt-Nickel	20

*See references on p. 126.

of ternary systems. A description of the phase boundaries in iron-chromium-nickel and iron-chromium-manganese alloys was given in Part I of this article (*Metal Progress* for July, p. 86); other ternary systems which have been investigated are listed in Table II. These systems form the basis of some of the high-temperature alloys; the formation of sigma in such alloys may have a serious embrittling effect.

Theories of Sigma Phase Formation – A number of theories have been proposed to account for the formation of sigma phase structures in binary alloys of the transition metals.

When sigma phase was known only in the iron-chromium and iron-vanadium systems, it was postulated that sigma was a superlattice of the AB type, but subsequent discoveries of this phase in other systems where the range of homogeneity did not include the equiatomic composition eliminated this possibility. The discovery of sigma in the iron-molybdenum system refuted the belief that the atomic number of the elements in a binary system must bracket manganese in order for sigma phase to be found in that system.

The theory of sigma phase formation in alloys of elements of the first long period has been described by E. H. Sully in the *Journal* of the Institute of Metals, Vol. 80, December 1951. The existence of isomorphous phases of a characteristic structure in different alloy systems at compositions which differ from one system to another has been satisfactorily explained by Hume-Rothery and his co-workers on the basis that the phase appears at a critical ratio of valency electrons to atoms. The most familiar of these are the beta-brass structure with an electron-to-atom ratio of 3:2, the gamma-brass structure with a ratio of 21:13 and the close-packed hexagonal structure with a ratio of 7:4. Such phases have come to be known as electron compounds. Sully has found good agreement between actual sigma phase limits of several systems and those calculated on the basis of an electron:atom ratio of 1.7. The results of similar studies made by other investigators confirm this value for binary alloys, as well as for the several ternary alloys investigated.

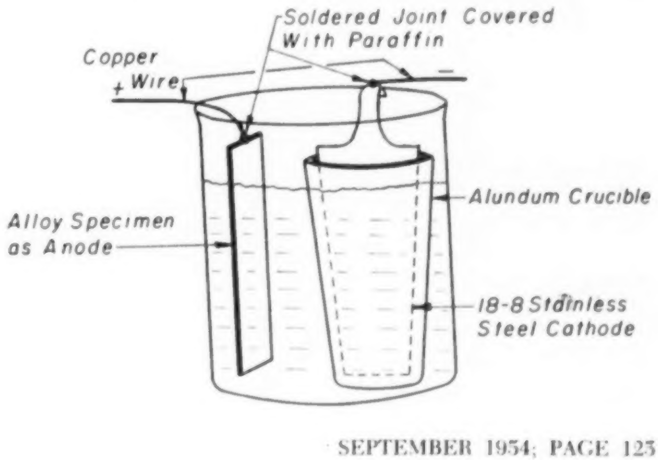
It has been suggested that the formation of sigma depends on the following two conditions:

1. The atomic diameters of the two alloying elements do not differ by more than 8%. (An exception to this is the Fe-Mo alloys where the difference is 10% but the structure is unstable below 2155° F.).

2. One of the two metals has a body-centered cubic structure while the other is face-centered cubic in at least one of its allotropic forms.

Chi Phase – Of recent interest is the discovery of the chi phase in iron-chromium-nickel-molybdenum alloys. This new phase has a body-

Fig. 5 – Electrolytic Extraction Cell for the Concentration of Minor Phases in Stainless Steels. Electrolyte is 350 g. ferric chloride in 1000 ml. water at room temperature in a 3-l Pyrex beaker; current density 0.125 amp. per sq.ft.; Crucible is Norton 9421 (P. K. Koh)



centered cubic structure of spacing $A_0 = 8.860$ kX which is sufficiently different from the sigma phase (with which it may coexist at the same temperature) that they may be easily distinguished. The chi phase has so far been found only in steels containing molybdenum and may be associated with the presence of that element. The possibility of chi being an intermediate stage in the formation of sigma is suggested by the work of P. K. Koh (*Transactions* of the American Institute of Mining and Metallurgical Engineers, Vol. 197, 1953, p. 339) who found only chi in Type 316 which had been annealed before aging, and only sigma in the same steel which had been cold worked prior to aging. Koh found chi in Type 316, ELC316, and 317, as well as in 23 Cr, 10 Mo and 27 Cr, 1.6 Mo alloys.

The Crystal Structure of Sigma

The true tetragonal symmetry of sigma was first established slightly more than three years ago by L. Menezes, J. K. Roros and L. A. Read ("Symposium on the Nature, Occurrence and Effects of Sigma Phase", A.S.T.M., 1950) who were able to isolate single crystals of sigma by careful fragmentation of brittle ferrite grains which initially were 1/16 in. in diameter. Prior to this work, it was believed that sigma was either triclinic or monoclinic because attempts to index the Debye lines from the sigma phase on the basis of a hexagonal, tetragonal or orthorhombic cell were unsuccessful. The tetragonal symmetry of sigma was confirmed by another team of researchers who determined the correct lattice parameters of sigma in the Fe-Cr system. A primitive teragonal cell containing 30 atoms with $a = 8.799$A* and $c = 4.546$A was discovered. Uniformly strong reflections coming from a number of high index planes suggested the positioning of 15 atoms at the point of a slightly distorted hexagonal net.

At about the same time, C. W. Tucker (*Science*, Vol. 112, Oct. 20, 1950, p. 448) described the beta-uranium structure as having an over-all tetragonal symmetry but pseudo-hexagonal along the c axis. On the basis of density measurements and the size of the unit cell (which was approximately the same as that determined for sigma), it was decided that the beta-uranium cell contained 30 atoms. Subsequent work by other investigators revealed that the sigma phase structure is the same as the beta-uranium structure as derived by Tucker and it was possible to index all the FeCr sigma phase lines on the basis of a 30-atom tetragonal cell with $a = 8.79$kX and $c = 4.55$kX. The only disagreement is in regard to the exact space grouping of the atoms; Tucker has chosen a P4/mnm group which implies a "puckering" of the hexagonal layers in uranium, whereas the P4/nm group proposed for sigma by J. S. Kasper and his co-workers necessitated that the hexagonal layers be flat.

*A stands for Angstrom unit.

Summary – Identification of sigma by microscopic methods can be fairly certain provided that a suitable etching procedure for a particular type of steel is chosen and that the size of the sigma particles is sufficiently large to be resolved. Difficulty is encountered when the particle size of the sigma and carbides is very small; then X-ray diffraction is often the only positive method of establishing its presence. However, because the amount of sigma and carbides present is often too small to be detected by conventional X-ray analysis of bulk material, the phases must be concentrated. Methods which have been used successfully include dissolution of the matrix by electrolysis in 10% ferric chloride solution or by immersion in a hydrochloric-picric acid solution after which the residues are cleaned and analyzed by X-ray.

Sigma phase structures have been observed in a large number of binary systems and it has been suggested that sigma is an electron compound with an electron-to-atom ratio of 1.7. The structure of sigma has been found to be identical with beta-uranium in that it possesses tetragonal symmetry but is pseudo-hexagonal along the c axis. The unit cell contains 30 atoms with lattice parameters of $a = 8.79$kX and $c = 4.55$kX.

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(*See Table II on p. 125*)

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(*Continued on p.* 128)

Sigma Phase . . .

(Continued from p. 126)

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Personal Mention

George V. Luerssen

Carl B. Post

Otto Zmeskal

George V. Luerssen ⊛, vice-president in charge of metallurgy of the Carpenter Steel Co., Reading, Pa., has retired after 47 years of service with the company. Some of the contributions made under his guidance include the development of free-machining invar, refinements in the magnetic properties of 30% nickel alloys, and establishment of procedures for controlling the hardenability and grain structure of carbon steels. He is a co-inventor of the torsion impact testing machine and helped develop a new low-temperature air hardening die steel. Mr. Luerssen is co-author of the textbook "Tool Steel Simplified".

Luerssen is a past chairman of the ⊛ Metals Handbook Committee, has been chairman of its subcommittee on steel melting since 1933, and chairman of the toolsteel subcommittee 1943-47. In 1945 he received the Bradley Stoughton Award of the Lehigh Valley Chapter ⊛. He was again honored in 1949 as the first person to receive the David M. McFarland Award of the Penn State Chapter for outstanding accomplishments in the field of metallurgical research. He is a graduate of Pennsylvania State University and a past chairman of the Lehigh Valley Chapter ⊛. He is also a member of A.I.M.E., A.S.T.M. and British Iron and Steel Institute.

Carl B. Post ⊛ has been appointed head of the metallurgical and research departments of the Carpenter Steel Co., Reading, Pa. Dr. Post has been chief metallurgist of the company since July 1951, and a member of the metallurgical staff since 1938. He is widely known for his research contributions in the fields of automotive and aircraft valve steels, particularly the addition of nitrogen for better workability and high-temperature strength. Other developments made under his supervision are in the fields of stainless steels and air hardening tool and die steels. Among his most recent contributions is the use of rare-earth elements, such as cerium and lanthanum, to improve the hot workability of corrosion resistant and heat resistant alloys. Among the awards held by Dr. Post is the Bradley Stoughton Plaque presented to him last year by the Lehigh Valley Chapter ⊛. This award is made annually to the Lehigh Valley metallurgist who has accomplished the most outstanding and generally useful work in the field of metallurgy. Dr. Post is a graduate of West Virginia University, and also holds a Ph.D. degree in physical chemistry from Pennsylvania State University. In addition to ⊛ he is a member of the Society of Automotive Engineers and the A.I.M.E.

Otto Zmeskal has recently been appointed research professor, department of mechanical engineering, College of Engineering, University of Florida. Dr. Zmeskal graduated from Armour Institute of Technology in 1936 with a B.S. in Chemical Engineering. After a summer as practice apprentice in Carnegie-Illinois Steel Corp. blooming mill he returned to Armour as instructor in chemistry and metallurgy, earning his M.S. degree in Metallurgy in 1938. He then entered Massachusetts Institute of Technology, receiving his Sc.D. in Physical Metallurgy in 1941.

Dr. Zmeskal then returned to Armour (by then combined with Lewis Institute to form the Illinois Institute of Technology) as assistant professor of metallurgy. While there he set up the radiographic laboratory and wrote a book on "Radiographic Inspection of Metals", published by Harper Brothers. In 1943 he became associated with the Universal-Cyclops Steel Corp., and was made director of research of the Bridgeville Division in 1944. In 1946 he was called back to Illinois Institute of Technology to initiate and direct a new department of metallurgical engineering.

He is a past chairman of the Chicago Chapter ⊛, and in 1953 he was granted the Society's Teaching Award. In his work in Florida, Dr. Zmeskal will conduct research and graduate teaching in metallurgy and assist in the development of the metallurgical industry and mineral resources of the State of Florida.

(Continued on p. 132)

Personals

Lucio Fausto Mondolfo succeeds Otto Zmeskal as director of the department of metallurgical engineering at Illinois Institute of Technology. Dr. Mondolfo and Dr. Zmeskal have written a textbook on "Engineering Metallurgy" soon to be published.

Charles A. Dietz, Jr. has been appointed plant manager of Technical Metal Processing, Inc., Cleveland.

George J. Fischer has been appointed director of the metallurgical department of Sam Tour & Co., New York City. A metallurgist at the Western Electric Co. for two and a half years, Mr. Fischer has also been an instructor at the Polytechnic Institute of Brooklyn, from which he holds bachelor's and master's degrees in metallurgical engineering.

John G. Thomas is now employed at the Crucible Steel Co. of America, working out of its central toolsteel sales office in Syracuse.

John K. Gibson received his B.S. in process metallurgy from the University of California last January and is presently taking the Allis-Chalmers graduate training course.

Duane H. Fiesel has accepted a position with Dow Chemical Co., Midland, Mich., as a research and development engineer in the experimental foundry section of the manganese dept., after graduating from Michigan College of Mining & Technology last May.

Elliott Rennhack recently accepted a position with the New Jersey Zinc Co. in the research dept. where he works on design of laboratory equipment and development of new processes.

N. P. Norlie is now general sales manager of the Wilbur B. Driver Co., Newark, N. J., after having served this company as western manager in Chicago for 25 years.

Arden L. Bement, Jr. received his metallurgical engineering degree from the Colorado School of Mines in May and is now employed at the Hanford Atomic Products Operation of General Electric Co.

Archie L. Spratt is now employed at Vanadium-Alloys Steel Co., Latrobe, Pa., in the metallurgy laboratory. He graduated from Massachusetts Institute of Technology earlier this year.

Peter E. Kyle has resigned as professor of metallurgical engineering at Cornell University to join Lessells & Associates Inc., Boston, as vice-president. He will supervise research and development in the fields of mechanical engineering, electronics, and mathematical physics.

C. A. Blesch is now with Heat and Control, Inc., San Francisco, where he is associated with **J. C. Harris, Jr.** and **Clark K. Benson**, in industrial process heating for the metal industry and other fields.

William C. Buell, Jr., who is widely known as an authority on steel refining and steel ingot practice, and for more than 20 years a member of the staff of Arthur G. McKee & Co. of Cleveland, has resumed private practice in Cleveland as consultant, specializing in matters concerned with steel ingot production.

Personals

Richard C. Hall is now employed as an engineer by the Magnetic Materials Development Laboratory, Westinghouse Electric Corp., Pittsburgh.

Robert J. Bradley has been appointed engineer in charge of the Reading Tube Corp., Long Island City, N. Y.

W. P. Wallace has left his position as senior engineer in the California Research & Development Co., Livermore, Calif., to become senior engineer for General Electric Co., Richland, Wash., in the fuel technology subsection, engineering dept.

Gilbert A. Jones graduated from the University of Illinois in June and is with Owens Corning Fiberglas Corp., Toledo, Ohio, in the metallurgical research department.

Marvin L. Kohn, having received his B.S. degree from Columbia University School of Mines, is now employed at Battelle Memorial Institute as a research engineer in the metallurgy department's welding metallurgy division.

Charles A. Licht, previously employed as special projects engineer at the Cleveland plant of Apex Smelting Co., recently joined the staff at U.S. Reduction Co., East Chicago, Ind., as chief engineer.

Frank D. Dougherty is now employed as a sales engineer with Crucible Steel Co. of America, Newark, N.J. He formerly was assistant to the products manager in the special products division.

E. O. Davis, charter member, has accepted a position with Houston Technical Laboratories, Houston, Texas, as production manager, and will be engaged in the manufacture and exploration of petroleum instrumentation and optical components.

James Albert Perdum has received his B.S. degree in mining engineering (metallurgy option) from Texas Western College and is now affiliated with Phillips Petroleum Co., Tulsa, Okla., as a metallurgical engineer in the test division of the engineering department.

William W. Fetzer received his B.S. in metallurgical engineering from Lehigh University in February and is now employed as metallurgical engineer at the Belle Works of E. I. du Pont de Nemours & Co., Charleston, W. Va.

Robert E. Fish, a recent army inductee, is undergoing basic training at Fort Knox, Ky., and has been assigned to the Army's Scientific & Professional Div.

Edward S. Jones has completed an assignment at the General Electric Research Laboratory in Schenectady, N.Y., and has been transferred to the materials laboratory at G.E.'s Aircraft Gas Turbine Division in Cincinnati.

Lieut. M. L. Anderson, Jr., formerly employed as a sales engineer for Ingersoll-Rand Co., Cleveland, is now attending the aircraft controller's school at Tyndall Air Force Base, Florida, as part of his 2-year tour of duty.

Personals

Thomas M. Baatz, a June graduate from Youngstown College with a degree in metallurgical engineering, is employed at Johnson Bronze Co., New Castle, Pa., in the research laboratory while awaiting his commission as 2nd Lieutenant, U. S. Army Artillery.

David F. Snow, on six months' leave from his job with Bridgeport Brass Co., is serving as director of the copper division, Business and Defense Services Administration, Department of Commerce, Washington, D. C.

Louis J. Fiedler has graduated from the Chrysler Institute of Engineering as a master of automotive engineering, and is now employed in the metallurgical research department of Chrysler Corp., Detroit.

David R. Shoemaker has completed his schooling at the University of Tennessee and is now affiliated with Tennessee Eastman Corp. in Kingsport, Tenn.

Herman Gardner has been transferred from the Wellington, Ohio, plant of the U. S. Plug & Fitting Co. to the Carrollton, Ohio, plant, where he will serve as general manager.

Milton F. Walther received a B.S. degree in mechanical engineering from the University of Texas in May 1954, and is now employed as a design engineer by the Lufkin Foundry & Machine Co., Lufkin, Tex.

Joseph F. Sisti has been released from active duty with the United States Navy, and has returned to his former position as metallurgical engineer with the Barber-Colman Co., Rockford, Ill.

Thomas G. Byrer, who received a B.S. in metallurgical engineering from Ohio State University last June, has accepted a position as metallurgist at the Chase Brass & Copper Co., Euclid, Ohio.

Gerald Abowitz, who holds a Campbell Fellowship for the academic year 1954-55, is now a research assistant in the department of metallurgy at Columbia University.

Dante Accinno, who has been on the staff of the Stevens Institute of Technology for over two years as research assistant on a U.S. Army Signal Corps engineering laboratory project, is still at Stevens, but is now research associate in metallurgy for the Reelshav Div. of Warner-Hudnut, Inc., New York City.

E. C. Larsen has joined the staff of the J. T. Baker Chemical Co., Phillipsburg, N. J., as technical director, and will be responsible for all research activities and the development of new business. Dr. Larsen was formerly chief engineer of the tungsten and chemical division of Sylvania Electric Products, Inc., Towanda, Pa. Before that, he was assistant research director of the J. T. Baker Chemical Co., and during World War II was on the research staff of the Bell Telephone Laboratories. Dr. Larsen received a B.A. degree from St. Olaf College in Northfield, Minn., and M.S. from Montana School of Mines. He studied in Germany under an international exchange fellowship at the Technische Hochschule Stuttgart; his Ph.D. degree was conferred by University of Wisconsin.

William J. Unterberg recently resigned from International Harvester Co., Milwaukee, to become assistant chief metallurgist with the Atkins Saw Div. of Borg-Warner Corp., Indianapolis, Ind.

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P9

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Personals

Ernest F. Nippes, Jr., has been advanced from associate to full professorship by Rensselaer Polytechnic Institute. Dr. Nippes is director of welding research at Rensselaer and has been engaged in a program of research authorized by the Wright Air Development Center in which he and his associates made experimental investigations into the flash welding of alloy steels.

C. K. Lockwood, vice-president of the stainless steel and alloys division of Shawinigan Chemicals Limited, Montreal, was elected president of the Alloy Casting Institute at the Institute's 14th annual meeting this summer, succeeding **Guy A. Baker**, vice-president of the Duriron Co., Inc., Dayton, Ohio. **E. A. Schoefer**, Mineola, N. Y., was re-elected to serve as executive vice-president and treasurer.

R. O. Hutchison has joined the Operations Research Division of Lockheed Aircraft Corp., Marietta, Ga., as staff specialist in nuclear engineering. Mr. Hutchison was previously chief project engineer in materials engineering at the Savannah River Operations of the U. S. Atomic Energy Commission in Augusta, Ga.

Howard H. Casey has been appointed director of engineering at the Midvale Co., Philadelphia, and will head the company's engineering, metallurgical and research staff. A graduate of Drexel Institute of Technology, Mr. Casey joined Midvale in June 1952. Prior to this, he was for 29 years with the Camden (N. J.) Forge Co.

M. L. Backstrom, formerly chief engineer at Firth Sterling, Inc., Pittsburgh, has been promoted to assistant sales manager. He joined the company in 1948 as a sales engineer after three years as a service engineer and assistant chief engineer with Voss Engineering Co., Pittsburgh.

Mattie F. McFadden is now materials and process engineer with the missile and radar division of Raytheon Mfg. Co., Bedford, Mass. Miss McFadden was formerly engaged in the same type of work for the Norden Laboratories Corp., Milford, Conn.

Case No. 107

Harris Steel Co. Reports:

- 4 Years' Trouble-Free Service
- Constant 24-Hour Operation
- Careful Control of Quality

Michael J. Giordano inspects test burner on one of twin Kemp Atmos Gas Producers.

Bright Annealing Furnaces Use Kemp Atmos Gas Generators to Supply Controlled Atmosphere of Uniform High Quality

Bright annealed steel is produced by Harris Steel Company, Kearny, New Jersey, with the help of two Kemp Model 6-MR Atmos Gas Producers. These two Kemp Generators burn city gas, to supply twelve furnace bases with purified controlled atmosphere.

Treating gas 24 hours a day, seven days a week, each Kemp unit produces 6,000 cfh of gas . . . enough to meet the needs of annealing 4,000 to 5,000 tons of steel per month.

User Reports Complete Satisfaction

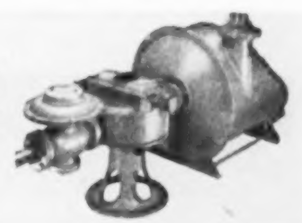
Mr. Harry Vane, Plant Superintendent, reports "These Kemp units have been in constant service for 4 years without a bit of trouble. The only maintenance needed has been ordinary routine. Because of the constant purity and qualitative analysis of the gas the Kemp Generators produce, we have been able to secure constant control of color, temper and quality of our output."

Kemp Can Help You, Too

If efficient, carefully-controlled supply of protective atmosphere gas can help you solve production problems, it will pay you to call in a Kemp Engineer for a detailed discussion of your needs. No obligation, of course.

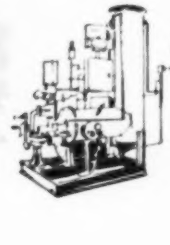
Write to: C. M. KEMP MFG. CO.,
405 E. Oliver Street, Baltimore 2, Maryland.

General view of Harris Steel Co. Bright Annealing Department, showing several of the 12 annealing furnaces supplied with Atmos Gas by Kemp Model 6-MR Generators.



This Kemp industrial carburetor—the heart of every Kemp installation—assures the desired analysis of protective atmosphere gas under any demand without waste . . . without frequent adjustments.

KEMP
OF BALTIMORE



ATMOS GAS GENERATORS

ADSORPTIVE DRYERS • SINGEING EQUIPMENT
IMMERSION MELTING POTS
CARBURETORS • BURNERS • FIRE CHECKS

Personals

John P. Frenck ⊕ has joined the Metals Research Laboratories of the Electro Metallurgical Co., Niagara Falls, N. Y., as a technical assistant in the metals research group. Other ASMembers who have been placed on the same staff recently are **Frank W. Hurd, William A. Krivsky,** and **Robert Peterson.** Dr. Hurd has been assigned to the engineering research group as group manager.

James G. Hess, Jr., ⊕, who received his M.S. in metallurgical engineering from the University of Arizona in May, is now employed as an engineer for the Shell Oil Co., Wilmington, Calif.

Richard H. Stevens ⊕, who graduated last spring from Missouri School of Mines and Metallurgy with a B.S. degree in metallurgical engineering, is now with the Aluminum Company of America in the fabricating works at Alcoa, Tenn.

D. I. Dilworth, Jr. ⊕, director of metallurgy for Crucible Steel Co. of America, has announced the appointment of **E. T. Walton** ⊕, formerly chief metallurgist at the company's Midland, Pa., works, to its central metallurgical offices in Pittsburgh in the capacity of metallurgical engineer. Mr. Walton has served with Crucible since 1923 in many administrative and supervisory capacities. **J. D. Dickerson** ⊕, chief metallurgist at Midland Works, has assumed Mr. Walton's former duties and will have complete responsibility for all metallurgical and inspection activity at that plant. Prior to joining Crucible in 1953, Mr. Dickerson was chief metallurgist for Republic Steel Corp. in Buffalo.

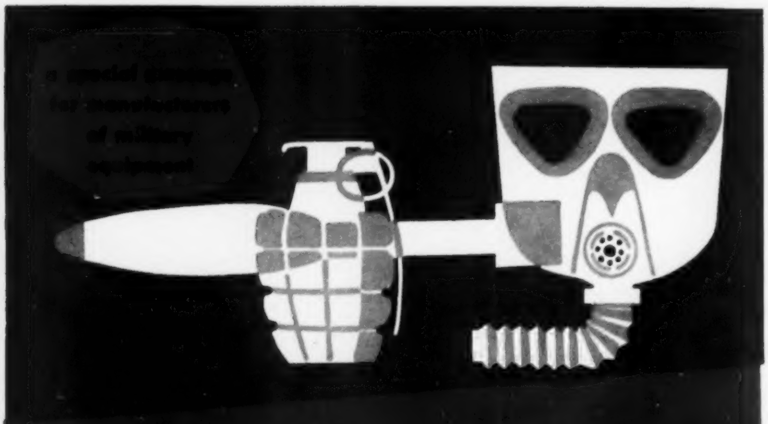
Henry A. Tobey ⊕ has been appointed factory manager of the Canton and Gambrinus, Ohio, bearing factories of the Timken Roller Bearing Co. Starting with Timken in the metallurgical department in 1928, Mr. Tobey became bearing factory metallurgist in 1940. He was made general superintendent of the Canton bearing division in 1948, a position he retained until his recent promotion.

Frederick H. Warren ⊕ has been appointed assistant to the executive vice-president, atomic energy division, General Dynamics Corp., Washington, D. C.

Charles R. Wirth ⊕ has been named district representative for the newly established west coast district office of the Eclipse Fuel Engineering Co., Rockford, Ill. He was formerly a sales engineer in the Rockford area.

Richard J. Rand ⊕ has been appointed manager of the Cincinnati branch sales office of Crucible Steel Co. of America. Mr. Rand joined Crucible following his graduation from Waynesburg College in 1940, and in 1953 was made assistant manager of the Cincinnati office. In his present capacity, he replaces **H. E. Friedlein** ⊕, who will act as special sales representative and consultant. Mr. Friedlein has been associated with Crucible Steel Co. of America for 45 years, and managed the Cincinnati branch for 19 years.

Thomas P. Bellinger ⊕ is now employed as materials engineer at the Essex Wire Corp., Logansport, Ind.



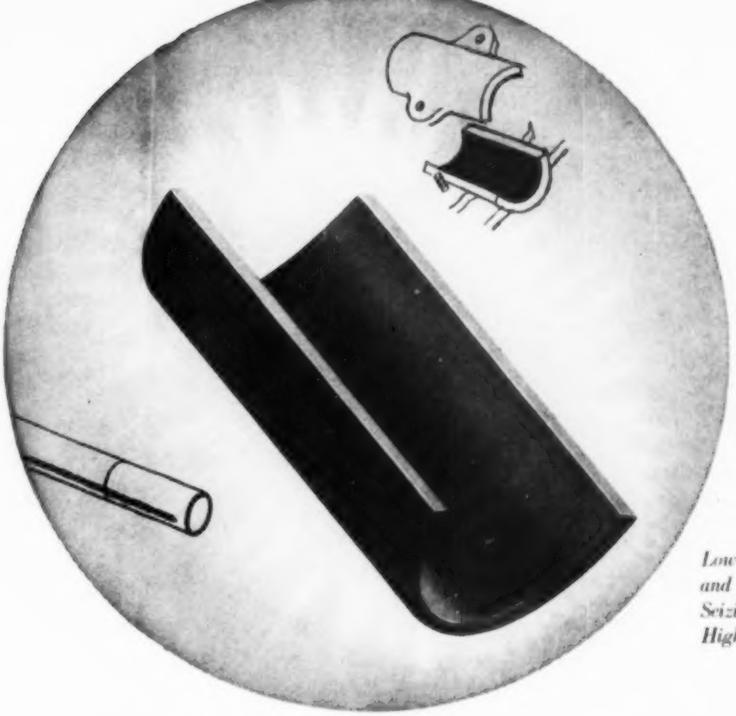
Lubricants for Nonferrous Metalworking*

THE INCREASING use of the scientific approach by lubricant suppliers and users and the ever-increasing demand for greater speed of production together with higher standards of quality makes any serious approach to the lubrication problem of interest. Because of this the meeting of the Metallurgical Engineering Committee of the Institute of Metals deserves more than passing attention.

The all-day meeting was carried on as an informal discussion, but unfortunately only a summary of the main points of the discussion is reported. Nevertheless, this summary holds much of interest and constructive suggestion for those engaged in metalworking operations. The morning session was devoted to lubricants for hot working and the afternoon session to cold working.

Underlying principles were discussed in connection with rolling, extrusion and forging, the benefit of wetting agents, and the use of glass fiber. The properties considered desirable in lubricants for cold rolling are described in relation to their function during rolling as well as their subsequent effect – as in annealing or storage – on the strip surface. Some of the problems associated with cold drawing are considered, such as the different requirements imposed on lubricants by types of machines used, kind of metal being drawn, and the speed of drawing. Medium-gage aluminum wire, for example, is now being cold drawn at speeds of 3000 ft. per min. At these higher speeds, higher temperatures are encountered at the wire-die interface and the mineral oils become less effective. It may be that refrigeration of the wiredrawing dies will be the answer; however, the aluminum wire industry must also find a drawing lubricant with the lowest possible viscosity because concurrently with the increase in drawing speeds, the capacity of the lubrication systems and the rate of lubricant circulation have increased. H. J. ROAST

*Digest of "Lubricants for Metalworking Operations in the Nonferrous Metals Industry", *Journal* of the Institute of Metals, Vol. 82, April 1954, p. 100-104.



Low Friction Bushings and Sleeves Resist Seizing, Abrasion, High Temperatures

HAYNES STELLITE Bushings and Sleeves

Trade-Mark

...for handling Hot-Abrasive Materials

Bearing parts made of HAYNES STELLITE alloy resist seizing and galling. They are hard and abrasion resistant, and will withstand the pitting effects of many corrosives. They take a high polish and are easy to apply. Use them to reclaim worn shafts or bearing blocks, and to lengthen the life of new equipment.

Operate with Little or No Lubrication

Sleeves made of HAYNES STELLITE alloy can be used in areas where efficient lubrication is impossible. They resist seizing even when lubricants are diluted by gasoline, cleaning fluids, and other liquids that wash out an oil film. They operate at peak efficiency even when lubricants decompose under heat, or are destroyed by abrasive particles.

Tough and Abrasion-Resistant

Bearing parts made of HAYNES STELLITE alloy resist the abrasive effects of wet or dry materials such as fly ash, coke, metal powder, shale, and cement dust. They are hard enough to carry heavy loads, and tough enough to stand up under repeated stress.

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These bushings and sleeves can be submerged in many acids, alkalies, and molten metals. Temperatures as high as 1500 deg. F. have little effect on their hardness, toughness, and dimensional stability.

For more information write for our 8 page booklet on half bushings and sleeves.

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Vitreous Enameling Keeps Pace With Production Practices*

PORCELAIN enamel finishes on sheet steel have come into widespread use on many varieties of consumer goods, including refrigerator linings, tops and oven linings of kitchen ranges, clothes washers and driers, water heater tanks, bathroom equipment, telephone dials, store fronts, gasoline pumps, signs and others. Recently the commercial enameling of aluminum has been introduced for architectural and industrial uses.

The finish, perhaps more accurately described as a vitreous enamel, is a fired glass coating. Originally it was produced by a dry process, involving the dusting of heated metal parts with glass powder and then returning them to a furnace for firing. Now it is universally handled by a wet process in which the powdered glass is suspended in a mixture of water and clay and applied to parts by dipping or spraying.

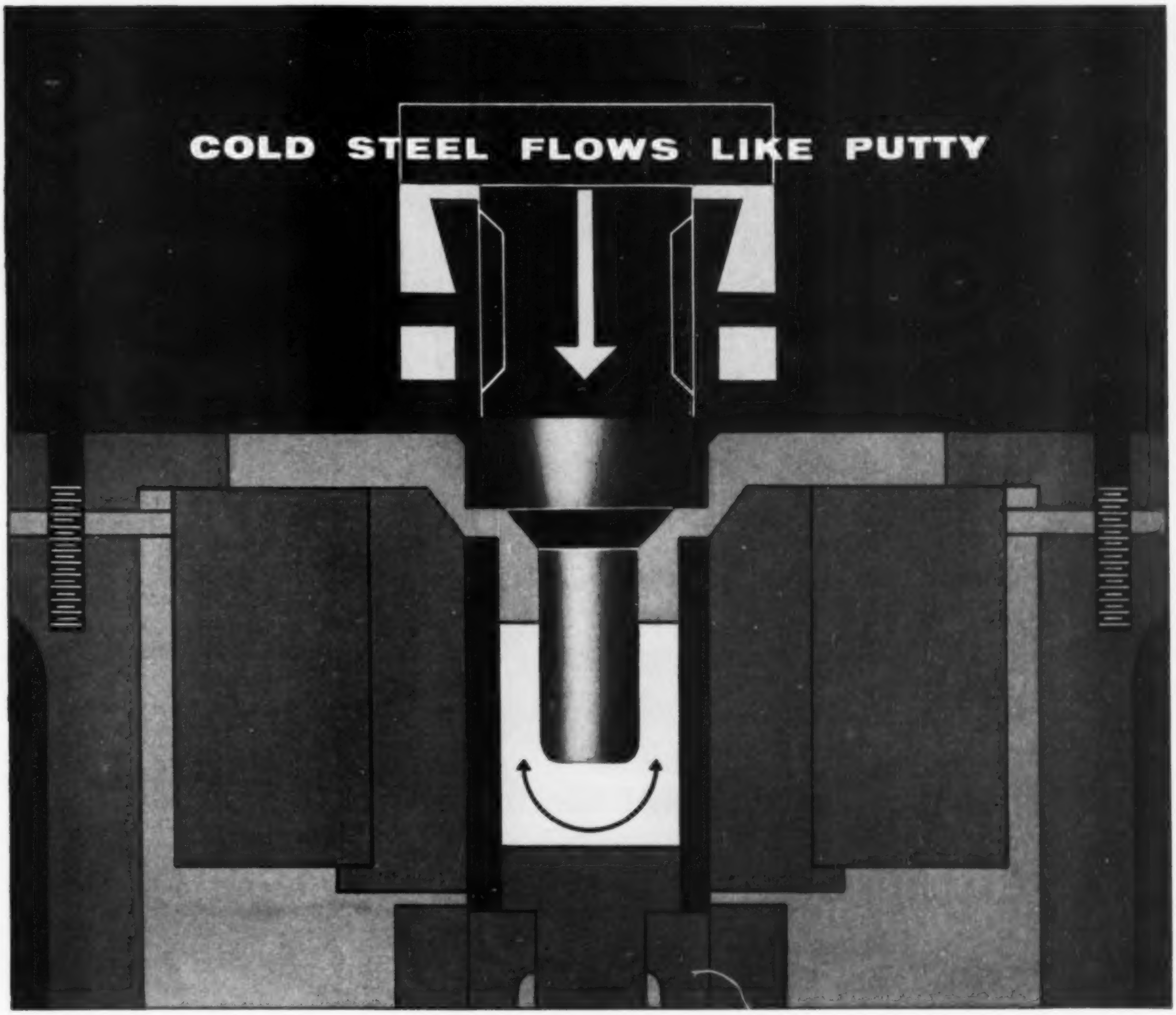
Since the enamel coating is glass, it acts as an impervious barrier, protecting the base metal unless disrupted in some manner, as by impact, bending, scratching or abrading. Once fracture occurs, the enamel cannot be restored. High resistance to most forms of chemical attack is characteristic.

Parts for household appliances usually are formed from steel sheets, ranging from 17-gage to 24-gage, a common grade being enameling iron, containing 0.01 to 0.04% C, a maximum of 0.1% Mn and a minimum of residuals. Such sheet stock has uniformly good strength at high temperatures, seldom gives rise to defects in the enamel and has a special surface texture suited to easy application and good adherence.

Difference in characteristics of various porcelain enamels is determined by the enamel glass, no single type incorporating all the desired qualities. Thus several varieties are mixed together in formulation of commercial frits. Principal glass-forming materials are silica sand,

(Continued on p. 148)

*Digest of "Porcelain Enamel: Its Use and Manufacture for Household Appliances", by Wilbur H. Pfeiffer, *General Motors Engineering Journal*, Vol. 1, No. 6, May-June 1954, p. 8-13.


COLD STEEL FLOWS LIKE PUTTY

Enameling . . .

feldspar, borax, fluorspar, cryolite, sodium silicofluoride, alumina, zinc oxide, soda ash, sodium nitrate, barium carbonate, lithium carbonate.

Combinations of some of these, predominantly silica, borax and feldspar, are used to produce clear colorless glasses, while in other instances coloring materials are added to form dark colored enamel frits. Cobalt, nickel and manganese oxides are added for ground-coat enamels; antimony, zirconium or titanium oxides may be added for white cover coats. Titanium-type white enamel is now in general use for most appliances.

Enamel is prepared by mixing the frit with water and relatively small amounts of clay and chemicals in a ball mill and grinding until almost all of the mixture passes 200 mesh. Successful application depends upon qualities of the clays. The latter must hold the frit particles in suspension until applied to the steel; they must hold the coating on the parts until firing is completed, and they must go into solution in the enamel glass during fusion, without discoloration.

While research is being directed toward some means of dispensing with the need for both ground and cover coats, general practice still is to apply the two, the ground coat to both sides of parts and the cover coat, by spraying, to one side only. Ground coats are fired usually from 3 to 4 min. at 1500° F. and cover coats from 2 to 3 min. at 20 to 50° lower temperature.

Time and temperature are rather critical, since they must be sufficient to dissolve clay and chemicals in the enamel, dispose of gases, develop a smooth surface and permit titanium compounds to crystallize or the colorants to reach the correct condition. At the same time, they must not be of a degree which would cause excessive acidity in the ground coat, or lead to solution of colorants or precipitation of the titanium dioxides in an unfavorable form.

Titanium dioxide is the most effective whitener or opacifier known for porcelain enamel, but its value depends upon proper crystallization from the glass. The crystallites should be wholly or predominantly of the anatase form and not rutile,

(Continued on p. 150)

Enameling . . .

since spectral reflectance of rutile is low at wave lengths below 420 microns, causing a yellow tone. Particle size also is important, those of 0.16 to 0.18 micron being blue, 0.32 to 0.45 micron yellow and 0.20 to 0.25 micron nearly neutral or achromatic.

When a ground coat is applied to sheet steel and fired, the following sequence of events occurs: The metal surface oxidizes; clay and some of the chemicals dehydrate; metal and glass give off gases; hydrogen is absorbed by the metal; melted glass dissolves iron oxide, clay and chemicals; melted glass wets the metal; dissolved iron oxide and bubbles migrate through the molten enamel; and stresses in the metal become relieved, with the metal distorting because of the differential heating and the pull of gravity.

As the parts cool, the glass reabsorbs gases and solidifies. Stresses and strains develop from the differential cooling and contraction between metal and enamel. Hydrogen becomes less soluble in the iron, resulting in pressures tending to force the enamel away from the metal surface. With insufficient adherence of the coating, this hydrogen pressure will disrupt the enamel in a circular area, producing a half-moon fracture commonly called fishscaling. This may not occur for several weeks after the metal has been enameled.

Another factor of top importance in the enamel-metal system derives from the fact that glass is strong in compression but weak in tension. Consequently, frit compositions are selected to give an enamel which will contract less than the base metal during cooling, leaving it in a state of compression. When a strain is imposed thereafter, it either creates more compression or it is absorbed in relieving compression so that failure does not result unless the strain is excessive, as in sharp bending, torsion or impact.

Ground coat thicknesses usually are in the range from 0.003 to 0.0045 in. For satisfactory appearance, white enamel exterior coats on appliances must reflect at least 75% of all visible light they receive. With titanium-type frits, this requirement can be met by thicknesses of 0.0025 to 0.005 in. A. H. ALLEN

Castings for Aircraft*

In two articles the Dayton editorial representative of *Aviation Age* discusses the possibility that the foundry art may be so modified and improved by modern techniques as to compete with forged parts or bit-by-bit fabrications, and usher in a revolution in the manufacture of large aircraft. Either of these alternatives will cause a severe bottleneck if aircraft production schedules are sharply enlarged, either because of shortages of equipment or trained personnel.

In 1947 the U.S. Navy Bureau of Aeronautics and Bureau of Ships started a comprehensive research into molding, melting and casting methods at Champaign, Ill., along lines already outlined in "Critical Points" in *Metal Progress* for July 1949. About three years ago, a limited survey on the possibility of using stressed castings in aircraft was authorized by the U.S. Army Air Forces, and later extended both in time and scope. The principal goals for this "Casting Potentials Project" are:

1. Compilation of a manual or handbook about castings and cast metal for designers in the aircraft industry.
2. Redesign of certain components of landing gear.
3. Their experimental casting by advanced foundry techniques.
4. A complete program of tests on these castings.
5. Pilot plant production of these proven components.
6. Evaluation of over-all costs in large-scale production.

In addition to existing facilities for pilot plant production, jointly owned by the contractor (Alloy Engineering & Casting Co.) and the U.S. Navy, a complete laboratory for stress analysis and full-scale testing is being installed.

To indicate the method of attack, a main landing gear trunion may be cited, conventionally made of forged A.A. 2014-T (14 S-T) aluminum alloy (56,000 psi. yield at 0.2% offset, 80,000 psi. ultimate, 9.5% elongation at fracture). The arm, shaped like a bell crank, is of I-beam cross

(Continued on p. 154)

*Digest of "Casting Potentials", by Lon C. Kappel, *Aviation Age*, May and June, 1954.

Aircraft Castings . . .

section – a shape readily forged but difficult to cast without internal flaws or stress concentration because of the accumulation of metal at intersections of web and flanges. In redesign for casting, this arm is a tapered tube, and the part is cast of aluminum alloy 220TA (49,000 psi. yield at 0.2% offset, 63,000 psi. ultimate, 4.5% elongation). At the test load of 4000 lb., the highest stressed region of the forging—at the bend in the arm—carries 70,000 psi., well past the yield and within 10,000 psi. of the breaking point, and is at an indicated true strain of 3.3%; in cast design and construction the highest stress at the bend in the arm is 52,000 psi. and at an indicated true strain of 1.0%.

Another landing gear trunion conventionally forged of aluminum with I-beam arm and weighing 60 lb., was redesigned and cast of alloy steel with tubular arms. The latter was heat treated to 170,000 psi. ultimate. The strength-weight ratios of the two designs are equal.

At present, cast parts are shunned by aircraft constructors. A survey made by the Aircraft Industry Assoc. indicated that their reasons are *(a)* low physical properties of castings, *(b)* poor quality, *(c)* inability to cast thin sections, *(d)* low strength-to-weight ratio, *(e)* low ductility, *(f)* poor dimensional tolerances, *(g)* poor inspection and control. The project under way is based on the assumption that these impediments are inherited from past experience with the product of commercial foundries which have small incentive to meet aircraft requirements and which are in fact using traditional techniques inherently responsible for poor quality and uniformity, and on the further premise that drastic changes in molding materials and methods, improvements in melting methods to avoid gas absorption or inclusions, and casting techniques which control feeding and cooling rates in all regions of the part will produce cast parts of high and uniform integrity and of utmost reliability in service.

The most recent survey of the Aircraft Industry Assoc. reports that "when improved castings approach forgings in strength and other fac-

(Continued on p. 156)

Aircraft Castings . . .

tors and when large castings of precise dimensions are available, there should be a greatly increased usage for structural parts of all sizes, from landing gears to wings", and comments that this would be especially true when the parts reach unmanageable size if present production techniques are still employed.

E.E.T.

Some Factors Which Affect Quality of Iron Ore Sinters*

The highly complex nature of the sintering process as applied to iron ores is revealed in this paper. The development of thin-section radiography has opened new possibilities of studies in this field, and some of the observations made with this new technique on various iron ore sinters are reported herein.

An iron ore sinter may be regarded as consisting of three fundamental types of structural constituents:

1. Original minerals which have remained unaltered throughout the sintering treatment.

2. Original mineral constituents which have readjusted their structure and shape by recrystallization in the solid state. These do not lose their chemical or physical identity at any time during or after the sintering process.

3. Secondary constituents which result from material that is fused or dissolved during sintering. These may be constituents which remain dissolved in a glassy slag or which crystallize on cooling in the form of fully developed dendritic crystals.

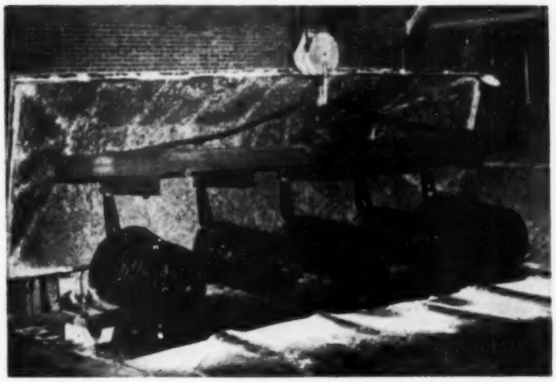
The main purpose of sintering is to produce large and physically strong aggregates with high porosity by bonding together fine ore particles. Two types of bonding are theoretically possible: bonding by diffusion and recrystallization of the fine ore fragments under the influence of heat, and bonding by slag formation by melting of easily fused constitu-

(Continued on p. 158)

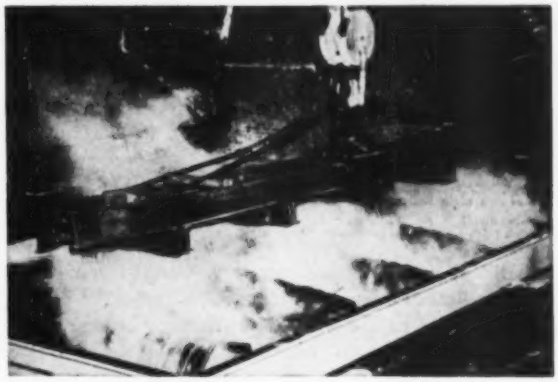
*Digest of "Sintering of Iron Ores", by E. Cohen, *Iron & Steel*, Vol. 26, Dec. 11, 1953, p. 620-624.

Descaling 5 tons of stainless wire

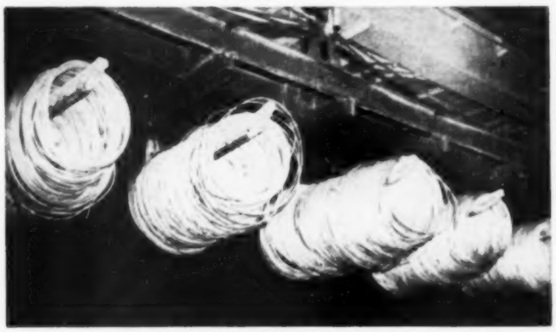
IN 15 MINUTES with VIRGO® Descaling Salt



10-MINUTE IMMERSION in molten bath of Virgo Descaling Salt at 900°F. loosens scale. The bath is self-regenerating, and produces no toxic fumes. Immersion time and temperature are flexible, need not be watched closely.



WATER QUENCH removes much of the loose scale. The steam generated by immersing the hot metal in the water further loosens scale by its blasting action. The work is thus prepared for the final acid dip.



THREE-MINUTE DIP in dilute acid removes the now soluble scale. The work is ready for a rinse or hosing to wash off the acid. **Result: a chemically clean surface—no pitting, etching or metal loss.** TOTAL TIME—15 MINUTES.

VIRGO DESCALING SALT—Producers and fabricators of stainless and alloy steels use Virgo Descaling Salt to quickly, positively remove scale produced by hot rolling, forging, extruding, casting, annealing.

VIRGO MOLTEN CLEANER—quickly, positively desands and degraphitizes castings; removes grease, dirt, chemicals, paint, enamel, rubber, atmospheric corrosion and other impurities.

This process can be used on steel; castings; forgings; fabricated parts; material to be salvaged. It employs simple equipment, and is easily adapted to your production methods.

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1-1443

Iron Ore . . .

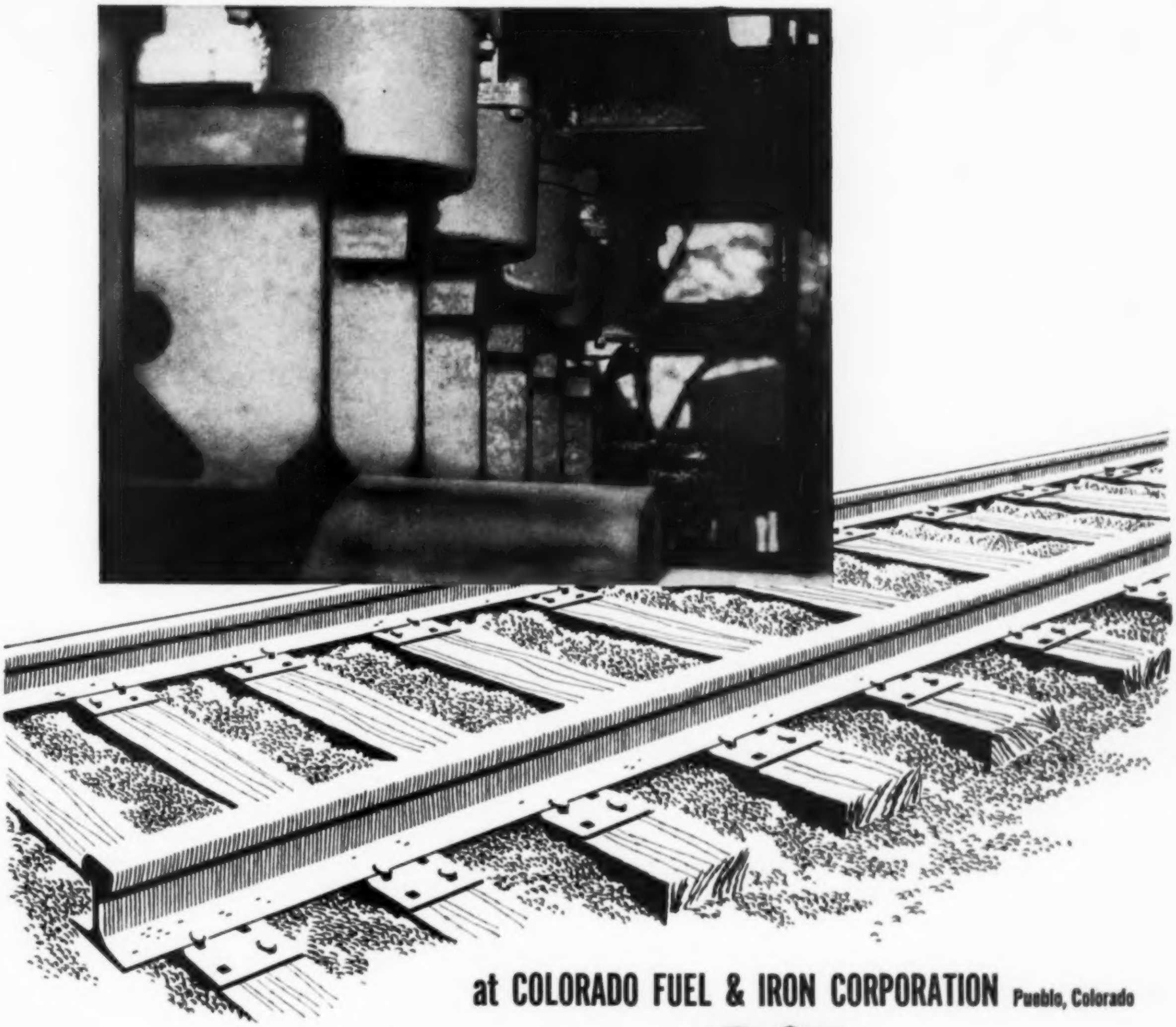
ents and the fritting of the ore particles together in a solid mass.

The experimental work involved sintering a sample of high-grade magnetite ore with varying mixtures of coke, flue dust (containing 15% carbon), and lime (CaO) in amounts from 0 to 5%; sintering a high-grade hematite ore (from Sierra Leone) with 6% coke, 30% sinter fines and 6% water; finally, sinters obtained from low-grade British ores (Northants and Fordingham) were studied after various degrees of heating. Samples of these products were then examined by radiographic methods to determine the structure of the sintered material (about 18 pictures of the various structures are shown and discussed in the paper).

Photomicrographs of the sinter obtained from the high-grade magnetite ore (Grangesburg) show an increasing disintegration of the original Fe_3O_4 ore particles as the percentage of carbon in the mix is raised from 2 to 5%. Sinters having the highest carbon content contained many tiny Fe_3O_4 crystals, formed during cooling, with a large amount of vitreous high-iron silicate slag; the 2% carbon sinters contained the original Fe_3O_4 grains of the unsintered ore. The high-coke sinters are hard and dense with low porosity while the 2% coke sinters are highly porous but have poor strength. The authors conclude that for this high-grade magnetite ore a mixture of 3% coke, 10 to 20% flue dust and 80 to 85% raw ore would produce the best structure after sintering. The addition of 2 to 5% lime to the Grangesburg ore mixes, together with 4% coke and 20% return sinter fines seemed to be beneficial. In every instance, crystals of monocalcium ferrite were found in the fused slag formed around the original ore fragments. These crystals apparently formed during cooling.

Sinters from a very fine hematite ore of high iron content (Sierra Leone) obtained from mixtures of 64% ore concentrates, (hematite of high iron content and of fine particle size), 30% return fines and 6% coke gave a different structure than those observed for the magnetite ores. A 4% addition of lime was also made to this mixture in one of the tests.

(Continued on p. 160)



Iron Ore . . .

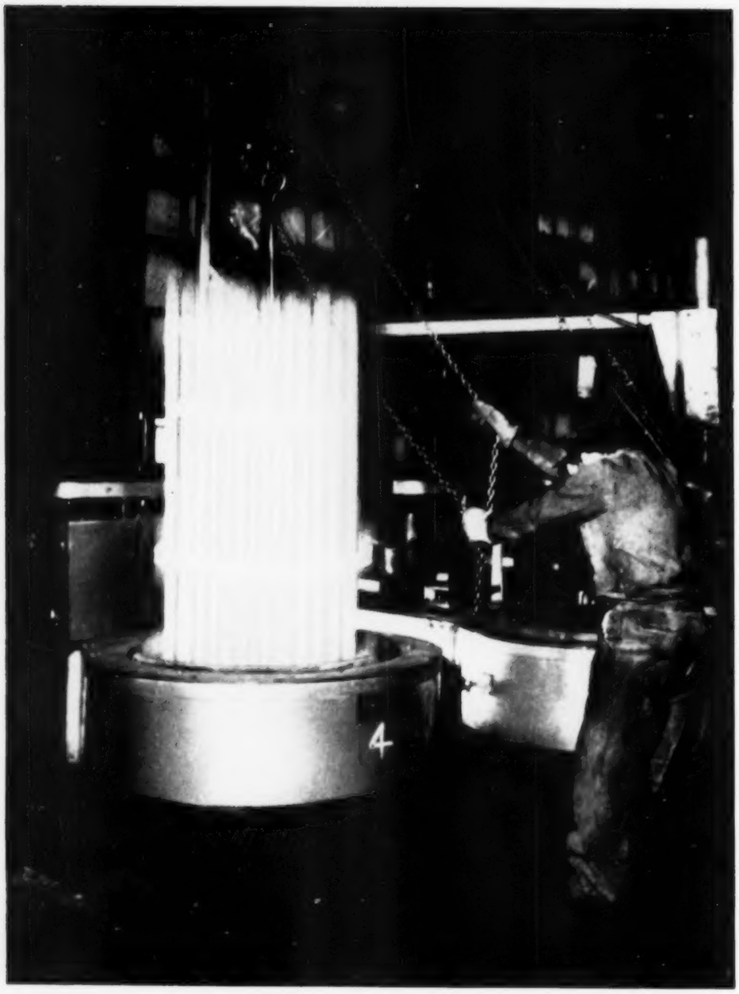
The hematite is largely changed to magnetite during sintering and the lime addition does not cause the formation of calcium ferrite (as in the magnetite mix) but appears as a calcium-iron silicate slag. This result may be due to the large amount of free silica in the gangue of the hematite ore. No pictures of these hematitic sinters are reproduced in the paper.

The sinters made from low-grade British ores such as Northants or Fordingham are even more complex due to the wide variation in the type of iron minerals. These low-grade ores contain several iron-bearing constituents in widely varying proportions such as iron carbonates, ferrous aluminosilicates, and several forms of hydrated ferric oxide. In addition, the gangue contains $CaCO_3$, clays, phosphates and gypsum. Free silica is almost entirely absent. The sintering of such material with different coke and lime additions leads to a very confusing series of structures and the making of a sinter of uniform quality from such low-grade ores is difficult on account of its continually varying chemical and physical properties.

The author reaches the following tentative conclusions as a result of this work:

1. The addition of lime to sinter mixtures which contain no free silica will prevent the formation of fayalite and other iron silicates.
2. If the sinter mix contains free silica, a lime addition will cause formation of calcium-iron silicate.
3. Lime additions promote the formation of the calcium ferrites and suppress the formation of the iron silicates.
4. Fuel content of the mix must be closely controlled and should be kept at a minimum that will produce a proper bonding slag.

It is obvious that each type of iron ore will present a different problem in any sintering operation, and that the chemical, mineralogical, and physical characteristics of both the iron-bearing constitutents and the gangue, are important factors. Much more work needs to be done on the sintering of any type of ore with varying amounts of lime, carbon, and water in the raw feed to the sintering machine. E. C. WRIGHT



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At this point is determined the final quality of your product . . . the amount of time and material wasted by sub-standard rejects . . . and *your ultimate operating cost!*

When you install a B & G *Hydro-Flo* Oil Quenching System you eliminate the warping and quality variations caused by uncontrolled quenching of heat-treated metal.

Oil is circulated at high velocity and with strong turbulence through the quench tank — then cooled and pumped back again. The oil in the quench bath is kept constantly at whatever temperature is desired. Since every batch is quenched under *identical conditions*, every batch is *identical in quality*.

While the individual components of an oil cooling installation can be purchased and assembled on the job, the trend today is to install completely factory-assembled oil cooling systems.

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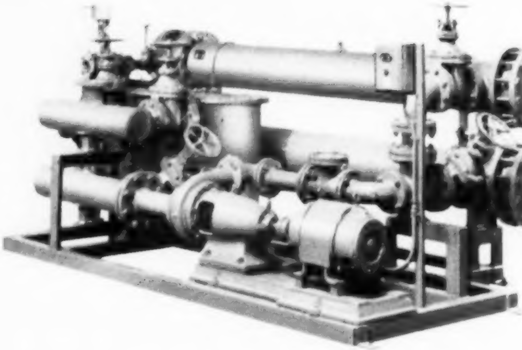

The B & G Self-Contained Oil Cooler illustrated here is pre-engineered and assembled complete at the factory. It eliminates the need for building pump piers and stands and for assembling pipe, valves, controls and wiring. Your only responsibility is to place the unit in position and connect it to the quench tank and water lines. It can be easily moved if a change in plant arrangement makes it necessary.

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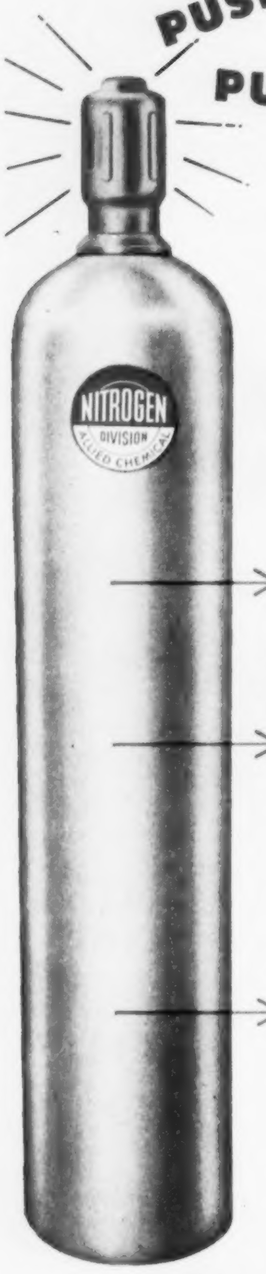


Review of Problems in Resistance Welding Coated Steels*

Literature on the resistance welding of coated sheet steel is lacking in fundamental data on metallurgical aspects, being confined principally to analyses of production difficulties. Furthermore, most available information deals with spot and seam welding, with little reported on projection or flash welding of coated materials.

Nonmetallic coatings, because of their high electrical resistance, are entirely unsuited to resistance welding. Welds made in sheet steel carrying phosphate, oxide or paint coatings are of poor quality, irregular in character, resulting in quick deterioration of electrodes and impaired corrosion resistance of the coating.

In respect to cadmium-plated steel, a combination of high electrode pressure (15,000 psi.), high welding currents and short weld times appears to meet general acceptance. Electrodes of chromium-copper alloy show best resistance to deformation under high pressure, and exhibit little coating pick-up after as many as 200 to 500 welds, given adequate cooling.

Low melting point of lead and terne plate coatings suggests a longer hold time and the likelihood of considerable electrode pick-up, requiring frequent cleaning. Effective seam welding of such coatings calls for higher than normal wheel loads and currents, although somewhat lower wheel speeds, with perhaps continuous cleaning of wheels.

Sheet steel plated with tin or tin alloy, in the consensus of investigators, is best welded with tip pressures around 15,000 psi. Electrode pick-up is less with tin-zinc alloys than with pure tin. This is minimized by high currents at short time intervals and efficient cooling.

Precleaning of aluminum-clad steel is advisable, either by scratch brushing and pickling or by simple degreasing and brushing. Again, high currents, short time and high

(*Continued on p. 164*)

*Digest of "Resistance Welding of Coated Steels", by J. E. Roberts, *British Welding Journal*, Vol. 1, May 1954, p. 233-237.

Resistance Welding . . .

tip loads are generally recommended.

Three types of zinc coatings—galvanized, sherardized and electrodeposited—are amenable to spot welding. The more consistent thickness of electrocoated material is productive of more uniform welds. Tests with electrodes cooled by refrigerant have shown a reduction in metal pick-up and better electrode life, but the cost of the cooling installation appears to outweigh the advantages it offers.

Failures have been encountered in seam welding of zinc-coated steel components, probably resulting from work hardening or strain aging of the base material. The condition may be aggravated by either the welding process alone or by zinc penetration of the strained metal during welding.

Metal pick-up usually will be encountered to greater or lesser degree in spot and seam welding of all types of coated steel. Palliatives such as refrigeration of electrodes or modifying the welding technique by the use of slope control of current, are not justified costwise. The best procedure is to accept whatever pick-up develops, provide an adequate supply of replacement electrodes and clean those which have become contaminated.

A. H. Allen

Internal Stresses in Forgings Minimized With Slow Cooling*

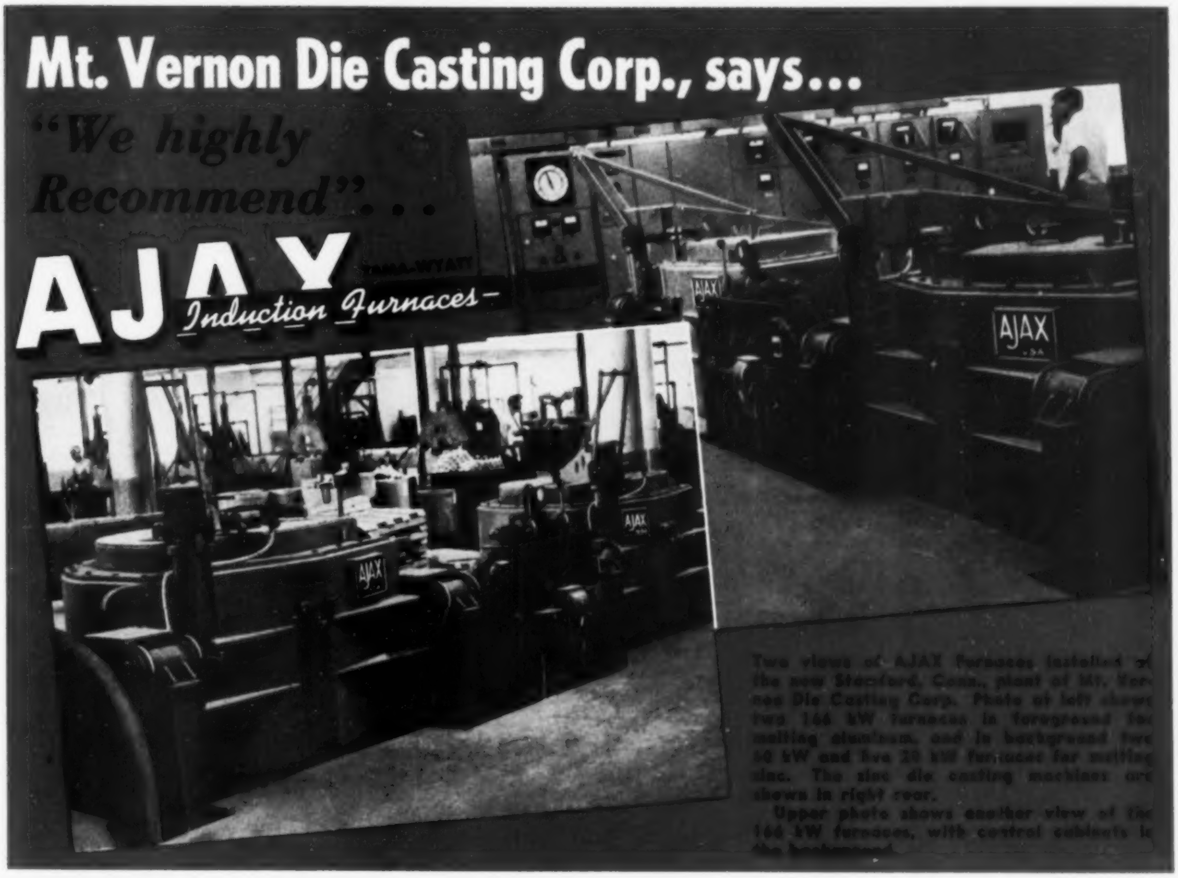
Large forgings often receive heat treatment which results in significant residual stress. This stress, of itself or in combination with service loads, may be of sufficient magnitude to cause failure. A knowledge of the causes of internal stress and of the means of minimizing it is, therefore, of considerable interest.

If the study is limited to cylinders, if simplifying assumptions are made, and if the physical constants of the material over the required temperature range are available, certain helpful equations can be written. Among these are: *(a)* the relation of stress during cooling to temperature difference between center and surface; *(b)* the relation of stress during cooling to the same temperature difference expressed in terms of surface cooling rate and diameter; *(c)* the relation of residual stress after tempering to the creep strength at the tempering temperature; and *(d)* the relation, during air cooling, of surface cooling rate to diameter for any surface temperature.

Both *(a)* and *(b)* assume elastic conditions with no relaxation due to plastic readjustment. Stress is shown to be directly proportional to temperature difference so that cooling rate is influential only as it affects this difference. The ratio of cooling rate to temperature differences varies considerably with temperature level, that required to produce the same difference and thus the

(*Continued on p. 168*)

*Digest of "Internal Stresses in Some Types of Forgings", by C. Sykes, a lecture given before the North East Coast Institution of Engineers and Shipbuilders in Newcastle-Upon-Tyne on Oct. 30, 1953, and subsequently published in the Institution's *Transactions*, Vol. 70.



Two views of AJAX Furnaces installed at the new Stamford, Conn., plant of Mt. Vernon Die Casting Corp. Photo at left shows two 166 kW furnaces in foreground for melting aluminum, and in background two 60 kW and five 20 kW furnaces for melting zinc. The zinc die casting machines are shown in right rear.

Upper photo shows another view of the 166 kW furnaces, with control cabinets in the background.

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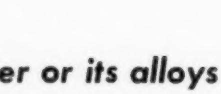

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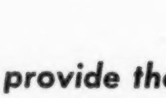

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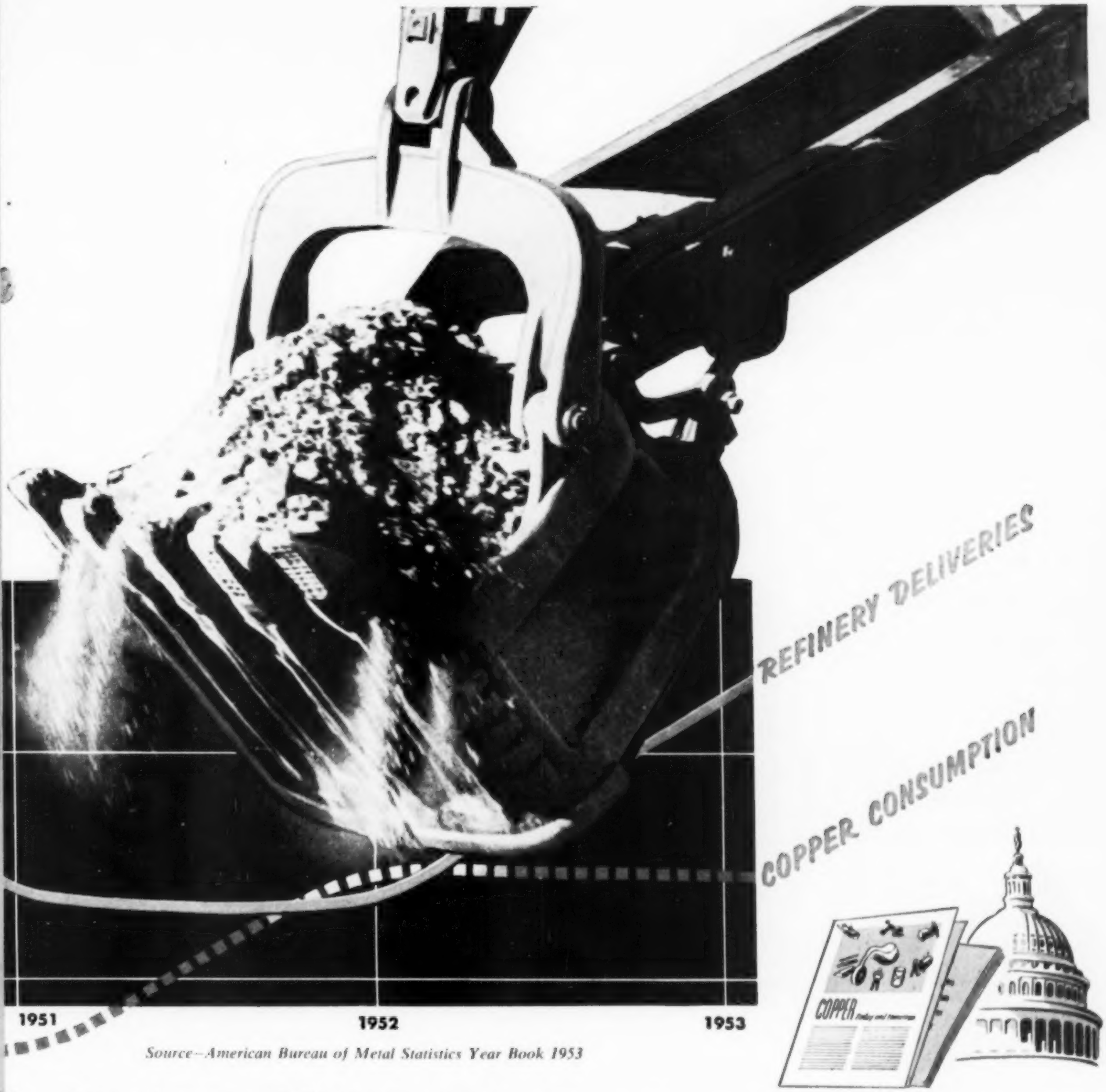

Source—American Bureau of Metal Statistics Year Book 1953

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Foreword, U. S. Dept. of Commerce B.D.S.A. Copper Quarterly, August 1954

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Internal Stresses . . .

same stress being three times as great at room temperature as at 1110° F. The stress caused by thermal gradients may be very high. In a cylinder a nominal stress of about 22,400 psi. results from a difference of 144° F. from outside to center.

In carbon or low-alloy forgings the high nominal stress indicated by the above does not persist undiminished beyond 660° F. because at higher temperatures the material becomes less capable of supporting high stress elastically. If no relaxation occurred there would be, in the absence of allotropic transformation, no residual stress after cooling uniformly to room temperature. Usually, however, almost complete relaxation does occur and with it a high residual stress. This stress is opposite to that which caused relaxation. Thus, in a cylinder the center is in compression during cooling but in tension once it has cooled throughout to room temperature. The accompanying tabulation, which assumes the presence of no transformation stress, shows that rather slow rates of cooling are necessary at 1110° F. if a low residual stress is desired in large rounds.

Diameter, In.	Cooling Rate in °F. per Hr., for a Residual Stress of		
	4500 Psi.	11,200 Psi.	22,400 Psi.
10	74	185	370
20	18	45	90
40	4.5	11	22
80	1.1	2.8	5.6

A nominal stress of 4500 psi. is considered reasonable for a final stress-relieving operation; 11,200 psi. is satisfactory for a forging cooled for rough machining prior to final stress relieving; 22,400 psi. might be deemed safe for ingots which are to be reheated for forging.

Insofar as residual stress is concerned, the natural cooling rates obtained in a furnace or in air are opposite to what we desire for greatest economy of cooling time. Uniform cooling at a uniform rate is inefficient because it does not take advantage of the fact that for the same residual stress the cooling rate at each temperature decrement should be accelerated. The cooling rate may be increased by an amount which causes an additional stress equal to half the "Hatfield time yield" at the corresponding temperature without significantly increasing relaxation. Hatfield time yield is defined as the stress which produces an average extension of 10^{-6} in. per in. per hr. over the period of the creep curve from 24 to 72 hr.

A program of cooling can be calculated on this basis to utilize a gradually increasing cooling rate down to the temperature at which the work may be removed from the furnace. Such a cycle may reduce the furnace time by one half and still be safer than conventional furnace cooling to room temperature. Below 660° F. normalized carbon steel will carry elastically a stress of 22,400 psi., and a cooling rate sufficient to cause this stress will not add to the residual stress. Because the surface cooling rate of rounds of any diameter at any temperature can be computed easily and accurately, and since stress may be determined from cooling rate, we can confidently select the temperature for removing the work from the furnace.

When phase changes are involved,

(Continued on p. 170)

Internal Stresses . . .

a knowledge of the isothermal transformation characteristics of the material is necessary for an analysis of the problem. When transformation occurs at 1110° F. or above, very substantial relief of the accompanying stress occurs as it proceeds. If it occurs at 660° F. or below, substantial residual stress remains. The problem is complicated in large rounds by transformation that does not take place isothermally, the heat evolved during transformation, and the difficulty of accurately determining the center temperature. Means are available of calculating the cooling curve of transformation in large forgings which check observed results satisfactorily.

Few large forgings are shipped today simply as normalized. There are, however, respected sources of information in the U.S. who would not consider it improper, for example, to ship carbon steel forgings over 24 in. diameter in the normalized and untempered condition so long as the carbon content did not exceed 0.35%. The doubtful wisdom of such practice is demonstrated by actual measurements showing that the stress at the center of a normalized 32-in. round with 0.30% C was 36,000 psi., whereas it was 27,000 psi. at the center of a 27½-in. round having 0.39% carbon.

Whatever the stress may be that results from cooling with or without transformation, it can be very nearly eliminated if tempering at a high temperature is permissible provided, of course, that the tempering is followed by a sufficiently slow cool to hold the residual stress below the permissible maximum. If the tempering temperature is such that the Hatfield time yield is no greater than 2200 psi., the unrelieved stress after a 10-hr. hold will not exceed 2500 psi. Since carbon and many low-alloy steels have a Hatfield time yield of about 2200 psi. at 1110° F., the normal tempering of large forgings reduces the stress to an acceptable level.

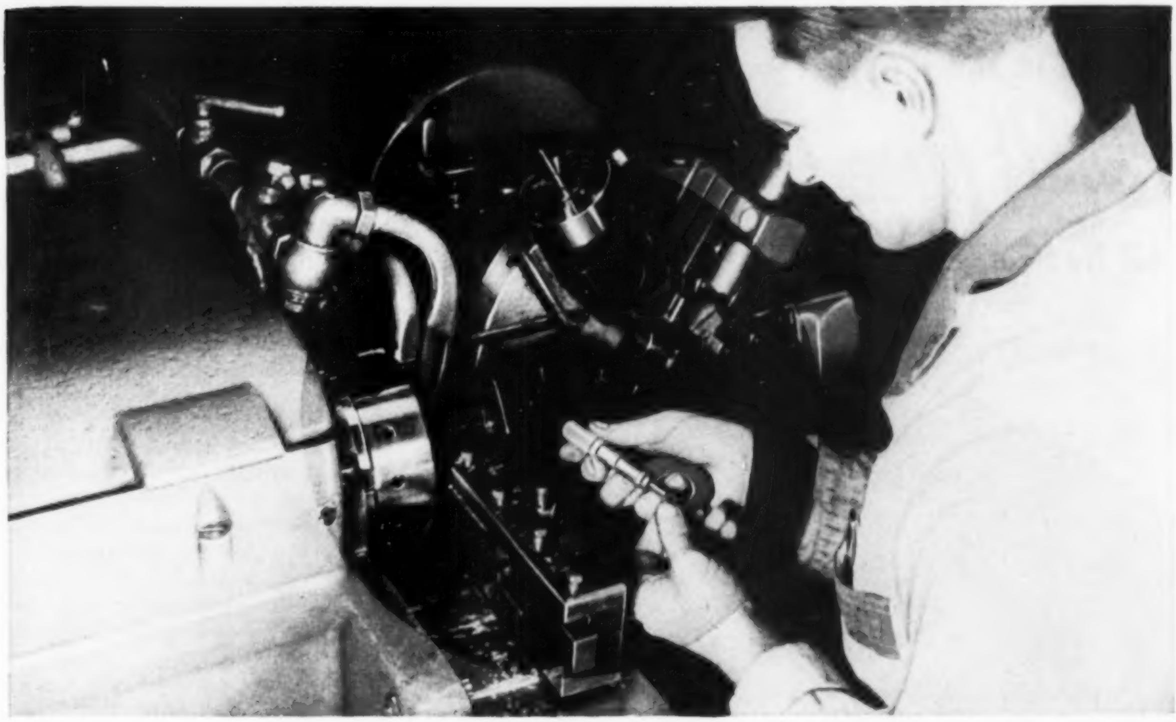
The simplifying assumptions which are made to facilitate stress analysis in cylinders during cooling are generally shown by experimental data to err on the safe side. Ingots up to 85 in. diameter have been faced smooth on each end prior to trepanning, and measurement of the shrinkage of the trepanned core relative to the remainder has provided ample evidence of the safety of the assumptions.

Thermal stress analysis of many items is far more complicated than that of solid rounds, but considerable work has been done on familiar shapes. For example, stress distribution in hardened hollow cylinders has been measured by Sachs's boring-out method and has been calculated from physical constants and temperature distribution by Treppschuh. An analysis of the stress in disks also has been made by calculation and by measurement.

In the foregoing, heat treatment has been discussed purely as it affects residual stress. It is recognized that additional criteria may have to be considered such as temper brittleness, flakes, and others.

It is hoped from this discussion that engineers will be more fully aware of the problems involved and will appreciate the attention which is being devoted to the production of reliable forgings.

M. W. ACKER



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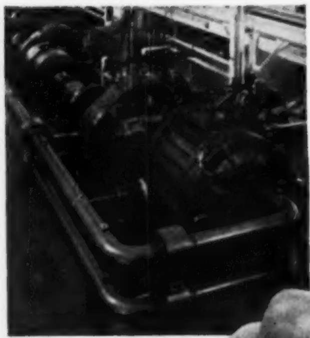

Upper: Waterbury Size 300 pump under test. Lower: Lebanon casting, machined ready for fabrication.

Character of Oxide Scales on Titanium*

A FURTHER step has been taken in the investigation of the products formed by the oxidation of titanium by pure oxygen between 1110 and 1700° F. at 700 mm. of mercury. The titanium strip was prepared from arc-melted titanium ingots by hot swaging and rolling operations performed in air at 1110° F. Scale was removed by a wire brush followed by immersion in 10% solution of nitric-hydrofluoric acids. The specimens of commercial titanium measured 1.75 x 1.5 x 0.2 cm., and those of the refined metal 1 x 0.5 x 0.1 cm. The specimens were suitably annealed and then treated so that the surface had an excellent polish, free from pitting, and was slightly etched to permit measurements for grain size.

The test consisted of placing specimens in a platinum-lined, glazed porcelain boat. Oxygen was supplied at 700 mm. pressure and suitable temperature control was provided. Glancing angle X-ray-diffraction technique was used to determine the structure of the oxidation products. It was found that in one respect titanium was unique in that the oxygen absorbed is distributed between a scale and a metal core. In the latter case the absorption was confined to the outer layers.

It was possible to remove the scales (which had a rutile chemical structure) as complete sheets from the underlying cores and so examine each separately. The refined titanium had thicker scales which protected the cores. At 1832° F. the scales heated in vacuum were absorbed by the cores. The presence of oxygen in the titanium lattice could be detected by an increase in hardness. At the low temperatures the scale is thin, dense, and slate-gray in color; at the higher temperatures the scale is thick, porous, and yellow-brown in color. Basic experimental research such as is described in this paper is of inestimable value in connection with the application of titanium to jet engine uses. H. J. ROAST

*Digest of "The Oxidation of Titanium at High Temperatures in an Atmosphere of Pure Oxygen", by A. E. Jenkins, *Journal* of the Institute of Metals, Vol. 82, January 1954, p. 213-221.

Scope of Application for Subzero Treatments*

In assembling metal parts, either by the expansion-fit or expansion-and-shrink-fit processes combined, the use of subzero temperatures is often advantageous. When certain steel and most aluminum alloy parts are assembled, damage caused by the necessarily high temperatures of shrink-fitting can be eliminated by subcooling the *internal* part. This expansion-fit process either reduces heating of the external part to a point where it causes no damage or eliminates it altogether, and may also replace hydraulic press equipment. A press-fit assembly that previously required tons of pressure can now be made by hand, thereby lowering manufacturing costs, increasing production, and avoiding strains being set up and scoring of mating surfaces. Some subzero applications include assembling cast alloy valve-seat rings in automobile cylinder blocks, placing an alloy steel ring around coining or cold forging dies to prevent splitting, assembling case hardened ring gears without tempering the case, inserting steel ball-bearing races in a cast iron housing, and assembling thousands of bearings and bushings of all sizes and shapes. Certain assembled parts, such as large bushings, may also be removed, if a tightly fitting cup-type container of subzero-cooled convection fluid is inserted.

Probably the most important application of subzero temperatures is delaying age hardening of aluminum rivets. Heat treated rivets of 17 S and 24 S aluminum alloy are stored at –40 to –50° F., immediately after quenching, and age hardening action is suspended for several weeks, in contrast to the two-day delay at 32° F. Thin sections and intricate parts made of 17 S and 24 S alloys, prone to become distorted if heat treated after forming, may be heat treated after blanking and stored at subzero temperatures until ready for forming.

Machine tool efficiency is increased by using a coolant because the heat generated at the cutting edge of the tool is a big factor in lowering wear resistance. Temperatures of 1100 to 1200° F., often attained at the cutting edge of high speed steel cutters, weld chip to tool as well as soften the cutting edge. Use of a coolant – even compressed air – passed through a refrigerated coil at subzero temperatures will reduce these temperatures and lengthen the tool life. Toolsteel cutters having low "red hardness", such as tungsten finishing steel, can be run under a subzero air coolant at higher speeds than normal without danger of losing hardness.

Precision parts can be stabilized in a matter of hours with subzero treatments. Machine tool castings no longer have to be subjected to outdoor weather conditions for several seasons and the U. S. Bureau of Standards has long since changed its requirement that certain gages be naturally aged for 6 years. An example where a high degree of stability is required is a set of plug gages worn undersize on one end and increased in size on the opposite end. Subjected to –160° F. for 5 to 15 hr., several of the gages increased in size from 0.0005 to 0.0008 in. per in. of diameter. Also, Rockwell C hardness increased two to three points. These gages were pre-World War I, aged for more than 30 years at room temperature. For most requirements for high hardness and dimensional stability, a series of

(Continued on p. 176)

*Digest of "Subzero Treatment of Metals", by H. T. Gregg, Jr., *General Electric Review*, July 1954, p. 19-21.

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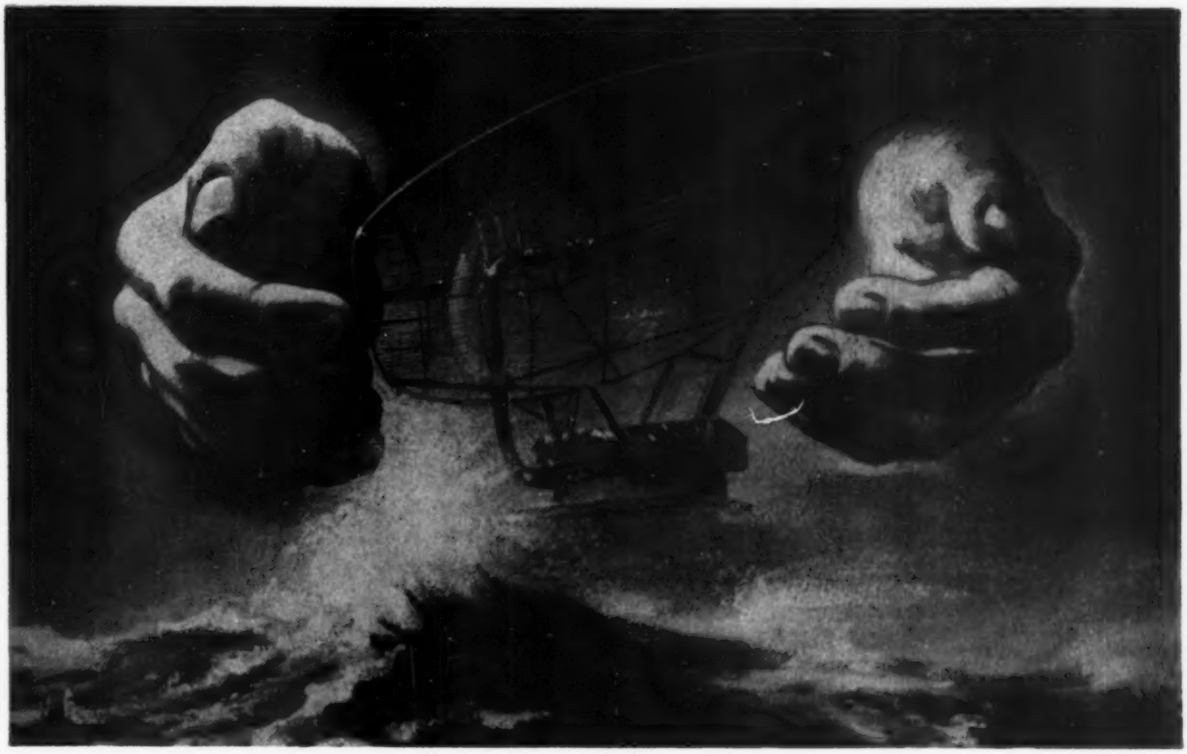

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Subzero Treatments . . .

treatments at about −150° F. is adequate. Gage blocks, cooled from room temperature to −120° F. five or six times during the final finishing operation, have been stabilized to within 0.000002 in. A low-temperature draw – low enough to maintain a hardness of Rockwell C-65 in the block – usually follows each subzero cycle.

The use of subzero treatments as a supplement to heat treating is one of its more recent applications. The percentage of untransformed austenite in cooled or quenched steel can be reduced considerably if quenching is done at subzero temperatures. As cooling reaches approximately −120° F., only a negligible amount of untransformed austenite remains. The increased volume and hardness resulting from this conversion of austenite into martensite means that an improperly heat treated tool or die that has shrunk when quenched can often be salvaged by subzero treatment. If ball-bearing steels, such as the S.A.E. 52100 are treated at −150° F. after the first temper, hardness will be increased by several points.

While there is little doubt as to the usefulness of very low temperatures in such processes as assembling, controlling age hardening, and machining, its usefulness in the heat treatment of steel is still disputable. The use of subzero temperatures in metallurgical operations is largely unexplored, but it is believed that the availability of practical low-temperature refrigeration will expand its use. C. T. Finley

Commercial Feasibility of Titanium Castings*

An attempt was made to answer some of the questions which have been raised regarding the commercial feasibility of titanium castings. These questions are:

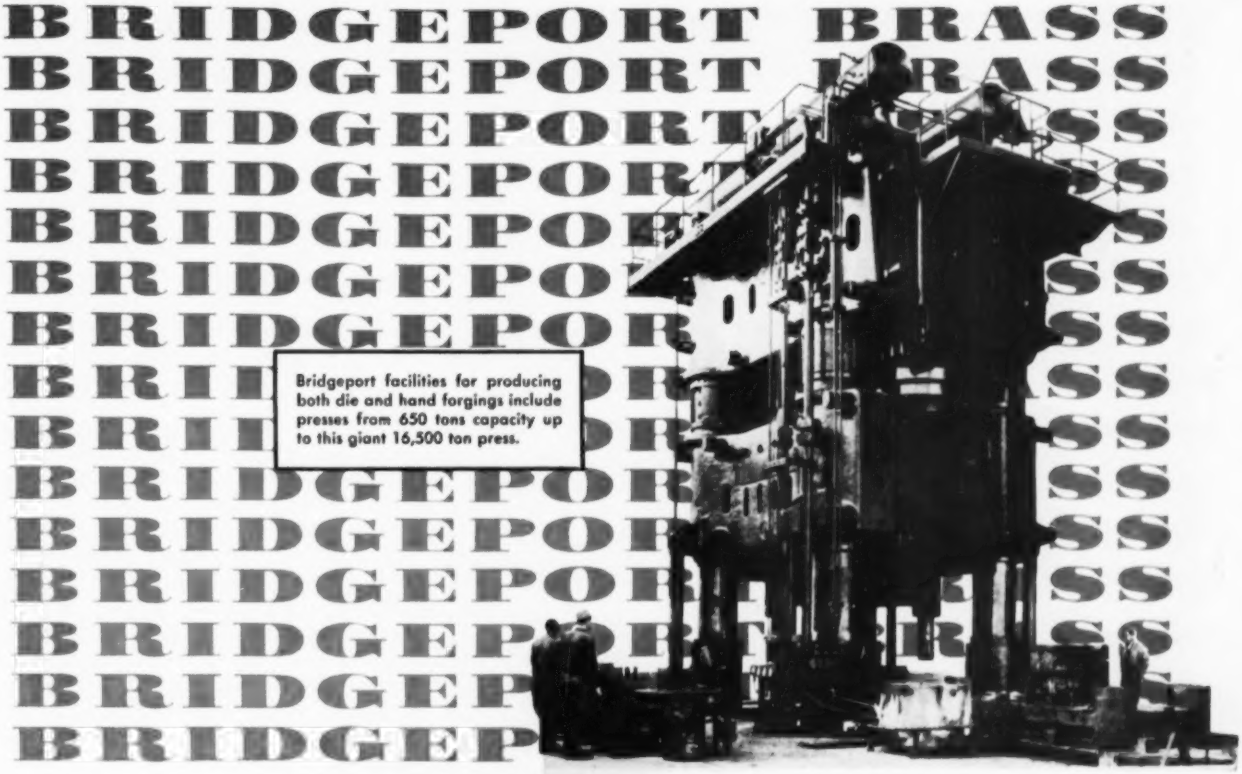
1. Does a noncontaminating mold material exist?
2. Can titanium castings be made which are nonporous, free of surface defects, and dimensionally accurate?
3. Can chemically homogeneous titanium alloy castings be made?
4. Will cast titanium have as good mechanical properties as wrought titanium?

All castings prepared for this study were made in a skull-melting furnace under an argon atmosphere. In skull melting, the center of the charge is melted with an electric arc while a thick layer, or skull, of unmelted metal is left between the melt and the crucible. This method of melting minimizes contamination from the crucible.

Mold refractories were evaluated by pouring 2-oz. heats of titanium into small refractory molds and measuring the hardness of the resulting castings. Hardness measurements indicated whether or not the castings were contaminated. Castings made in molds of silica, zircon, zirconia, beryllia, thoria, magnesia, alumina, and titanium carbide were all contaminated and were all considerably harder than the titanium charge. Those made in carbon and graphite molds had the same hardness as the titanium charge.

(Continued on p. 178)

*Digest of "Preliminary Survey of Some Metallurgical Bases for a Titanium Castings Industry", by R. F. Malone, H. T. Clark, S. V. Arnold and W. L. Finlay, presented at the American Foundrymen's Society Convention, Chicago, May 5, 1953.



Bridgeport facilities for producing both die and hand forgings include presses from 650 tons capacity up to this giant 16,500 ton press.

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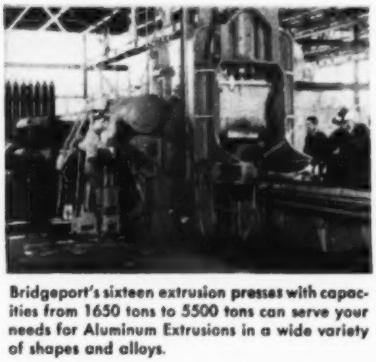

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BRIDGEPORT ALUMINUM

Titanium Castings . . .

Carbon molds chilled the casting less severely than graphite molds and permitted sharper reproduction of corners on the casting. Because carbon and graphite were quite promising mold materials, they were used to prepare titanium castings for further tests.

To obtain castings free of cold shuts and splashes, it was necessary to preheat graphite molds to 1470° F. and gate the castings from the bottom. Cylindrical castings weighing 15 to 24 lb. were made by this procedure. When poured under a reduced pressure of argon, a porous subsurface rim surrounded the castings. This porosity was reduced by casting at atmospheric pressure. Shrinkage in the castings ranged from 0.020 in. per in. for sections 2 in. thick, to 0.0126 in. per in. for sections 11½ in. thick.

Chemical analyses of samples taken from several areas in a cast cylinder of unalloyed titanium showed that there was very little carbon or nitrogen contamination from the graphite mold. The carbon content of this casting was 0.03 to 0.04% and the nitrogen content was 0.02 to 0.03%. Titanium sponge from which the casting was prepared contained 0.02% C and 0.02% N.

A titanium alloy casting with 4% Al and 4% Mn weighing 24 lb. was analyzed for homogeneity. Five samples taken from different portions of the casting all had about the same chemical analysis. From these results, it was concluded that skull melting could be used for making chemically homogeneous titanium castings.

The mechanical properties of an unalloyed titanium casting and an all-alpha alloy casting (7% Al) were comparable to those of similar wrought titanium alloys. Although the strength of an alpha-beta cast alloy (4 Al, 4 Mn) was greater than that of a similar wrought alloy, its ductility was much lower. Therefore, it appears that this alloy is not suitable for casting purposes.

Basically, titanium has good castability, and titanium castings are commercially feasible. However, it may be several years before all the technical problems involved in casting titanium are solved.

R. M. Lang

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Welding, Metallurgy and Design in British Shipbuilding*

THE USE of welding in merchant shipbuilding in Great Britain has developed steadily without abrupt change-over from riveting as in the United States. Such rapid change-over has brought some unforeseen and distressing problems in world shipbuilding.

Notch-toughness at service temperatures in mild steel has been shown to be of great importance in avoidance of brittle failures. Consequently, the shipbuilding industry collaborated with steelmakers and metallurgists in an intensified research program. Much has been learned, but much is yet unknown. Early attention was directed to chemical composition and it was found that in ship plate used during the war, carbon content was high and manganese content unusually low. This was corrected with a higher manganese-to-carbon ratio. Structure of the steel was then studied and these studies revealed that notch-ductility decreased with plate thickness. Strain aging was also shown to be of importance. For special quality steel, in addition to increasing the manganese-to-carbon ratio to obtain high notch-ductility at low temperatures, it is necessary to use aluminum-killed steel and to give it a normalizing treatment.

Much work has been done with laboratory tests and their correlation to service failures. Two types of tests are in use in the United Kingdom, both of which use plate specimens. Work has been done on the interpretation of surface markings associated with brittle failure. From these studies it has been found that the process of propagation of brittle failure in a plate consists in the formation of successive disk-shaped cracks originating ahead of the main fracture front. The Admiralty Ship Welding Committee has given much attention to the choice of the most suitable test for assessing notch-toughness. They believe that a single

(Continued on p. 182)

*Digest of "Aspects of Welding Research in British Merchant Shipbuilding", by R. B. Shepheard, *Welding Journal*, Vol. 33, January 1954, p. 23-40.

British Ships . . .

standard test is preferable and have recommended the general adoption of the Charpy V-notch impact test.

Fundamental research has also been carried out. This includes work on pure iron and pure iron alloys performed by the National Physical Laboratory. The rules of Lloyd's Register were amended in 1949 to provide for certain ratios of manganese and carbon contents in quality ship plate over ½ in. thick. For structural parts exceeding 1 in. thick it is required that properties and processes of manufacturers of the steel are to be specially approved for the purpose. Steelmakers are invited to submit for approval steels which they can readily and consistently produce. They must furnish full details of manufacture. Notch-bar tests of samples are then carried out. From the available data the suitability of the material is determined. If the steel is considered satisfactory, approval for its use is granted on the understanding that substantially the same analyses and processes of manufacture will be maintained. Impact tests are made periodically. This is an approach quite different from that in the United States.

Studies of residual or locked-up stresses have demonstrated that such stresses probably cannot be controlled after welding. While under certain conditions the presence of residual stresses must be considered to reduce the load factor for elastic instability, they cannot be considered to affect the static capacity of a structure provided the material behaves in a plastic manner. It has been shown that where no notch is present high residual stresses of themselves cannot produce brittle failure. In the presence of a notch, residual stresses cannot be ignored in a material which is notch-brittle.

Great interest is being shown in aluminum alloys for use in shipbuilding, although high cost has restricted their use. Heat treatable and nonheat treatable alloys of the aluminum-magnesium and aluminum-magnesium-silicon types have been used and much research has been done to improve their weldability. Inert gas processes have been used.

Much work has been done on arc characteristics. The fundamental

(Continued on p. 184)

Tool Steel Topics

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

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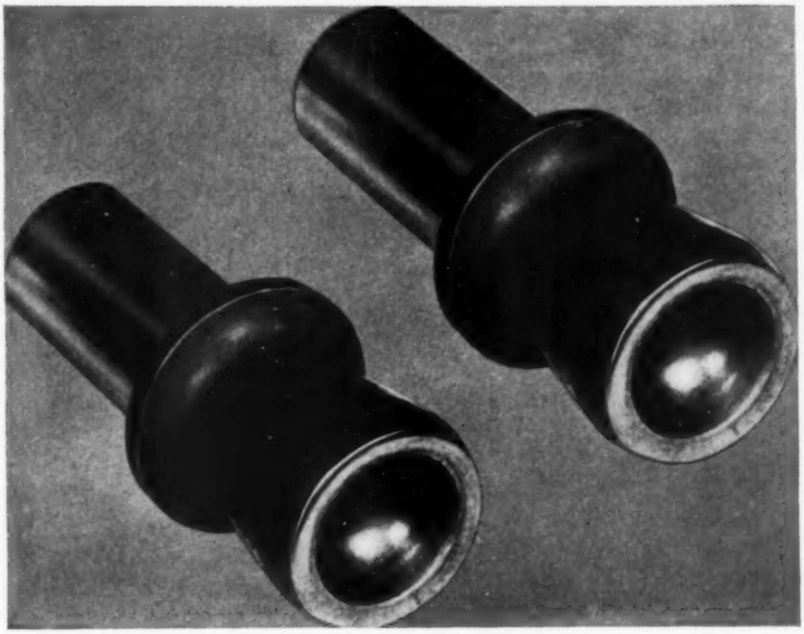

Boiler Shop Using Bearcat Rivet-Sets Ups Average Run from 300 to 2470

The mechanical department of a large boiler shop had trouble driving more than 300 hot rivets, using standard rivet-sets. Once that mark had been reached, the sets would crack or spall. Sometimes re-cupping saved the day, but oftener than not the sets had to be replaced.

We were sure they could get longer runs with rivet-sets of Bearcat tool steel. The management gave Bearcat a trial, and put six sets to work after a heat-treatment cycle consisting of preheating at 1200F, air-quenching at 1750, and tempering at 550.

The results were even better than expected. The average run increased from 300 to 2470 before recupping was required. Not only that, but the recupping was accomplished without heat-treatment, which of course is a frequent source of trouble with rivet-sets of carbon tool steel.

Bearcat is an ideal tool steel for the manufacture of rivet-sets because of its superior shock-resistance. It is also well suited for uses where hot-work properties and easy machining are essential.

BEARCAT'S BIG FEATURES

1. Super shock-resistance
2. Deep-hardening . . . in air
3. Machines easily (Brinell 197 max)
4. Low distortion in heat-treatment
5. Good hot-work properties
6. Easily carburized for long wear

Typical Analysis

C	Mn	Si	Cr	Mo
0.50	0.70	0.25	3.25	1.40

In addition to being used for rivet-sets, Bearcat is ideal for such hot- and cold-shock applications as chisels, punches, hot headers and gripper dies. It has many other uses, too — master hobs, engraving dies, die-casting dies, and short-run dies used in cold-forming, blanking and bending.

You'll be well pleased with the service life obtained with Bearcat. We stock Bearcat in our mill depot. Or you can obtain a supply through your local Bethlehem tool steel distributor.

BETHLEHEM TOOL STEEL ENGINEER SAYS:

Use Care When Hardening Hot-Work Tools

Although hot-work tools can be hardened to Rockwell C-56-60, there are hardly any applications where such hardness is beneficial. The majority of hot-work tools are used in a hardness range of C-41-44, or C-46-49. On new hot-work applications, a common mistake is to heat-treat to a hardness level which is too high for the application, with the result that rapid heat checking or breakage occurs.

For example, put tools of our Hot Work 8 analysis to work at C-55 or higher, and chances are, they will fail prematurely. Yet these same tools, used at Rockwell C-52 or lower, will give outstanding service.

On every hot-work application the best hardness level must be determined by experience. There's always a compromise involved, as the highest hardness is best for wear-resistance, and the lowest hardness is more resistant to heat-checks. Our suggestion? To be sure of maximum service, don't overharden hot-work tools.

IT'S A-H5 FOR LONG PRODUCTION RUNS

This high-production die, made of A-H5, blanks and punches sheet steel of 0.180-in. thickness. A-H5 makes possible long production runs between grinds. It holds a durable cutting edge, and resists distortion in heat-treatment.

British Ships...

physics of heavy current, high-voltage arc discharge has provided useful basic knowledge on the welding arc. This has been of particular value in the study of the "Argonarc" welding process.

A series of full-scale structural tests on welded and riveted ships has been undertaken. The program is in two stages: *(a)* in still water and *(b)* under service conditions at sea. Certain classes of tankers and dry cargo ships practically identical in design and of both welded and riveted construction were available. Tests showed no significant difference between similar welded and riveted ships in the general stress distribution and deflection in the main hull girder. The results correspond to those predicted from conventional beam theory. No evidence was found of rivet slip nor of support for a commonly held belief that welded ships are stiffer. Extensive sea trials were performed to determine forces acting on the hull. The analysis of the resulting data, a lengthy and formidable task, has just been brought to completion.

During these full-scale ship tests, opportunity was taken to secure information on vibration, in order to develop new methods and to improve existing methods of calculating critical frequencies of ships' hulls. Among other results the tests showed that critical frequencies in both welded and riveted construction are closely in agreement. The welded ship, however, tended to have larger vibration amplitudes, suggesting that structural damping is greater in the riveted ship.

Many welded dry cargo ships have developed corrugations in the bottom plating between floors. The bottom plate of these ships is drawn in slightly during construction due to thermal contraction at the connecting fillet welds. This dishing, or unfairness, progresses in service under repeated compressive loading combined with hydrostatic pressure. This progressive unfairness is evidence of the increased compressive stresses in the bottom structure of the modern cargo ship.

In contrast to aircraft, there is little evidence that fatigue strength rep-

(Continued on p. 186)

British Ships . . .

resents a basic criterion in the design of ships' structures. A resonance vibration method has been used to duplicate the fluctuating loads to which hull components are subjected. A main feature of the work was to determine the effectiveness of different forms of reinforcement in certain types of butt welds. It was found that under fatigue conditions these reinforcements tended to reduce the strength due to the discontinuities introduced and that the most effective connection was formed by direct butt welds of high quality.

Methodical and informed supervision of welding and weld inspection is necessary to maintain good standards of workmanship. Precautions must be taken to avoid cracking in welds. Radiography has proved a most valuable technique for the control of shipyard welders. There is a trend in the United Kingdom toward the use of radioactive isotopes in place of X-ray apparatus.

Structural design is an important factor. Sharp discontinuities or notch effects must be avoided to all practical limits. The eye of the designer or draftsman must be specially trained to detect and smooth out stress concentrations. In recent years significant changes have occurred in the general design of merchant ships. There is a trend toward increased weight with decreased buoyancy at the ends. Hogging moments in the loaded conditions are consequently more severe than those in cargo ships of the past, for which sagging in ballast was the more critical condition. In many welded ships the resulting compressive stresses in the bottom platins have led to the development of corrugated plating already mentioned.

Reviewer's Note – For parallel developments in the United States the reader is referred to the Third Technical Progress Report of the Ship Structure Committee, and to a paper entitled "Research Under the Ship Structure Committee". Both are contained in Bulletin 16 of the Welding Research Council, 29 West 39th St., New York 18, N. Y. (See also the series of articles on brittle failures starting on p. 83 of this issue of *Metal Progress.*)

M. E. Shank

Zirconium Additions Inhibit Grain Growth in Extruded Al*

NONUNIFORM grain size is commonly found in aluminum extrusions – in particular, a localized zone of coarse grain is frequently found after heat treatment, forming an anulus within the section or sometimes a ring around its circumference. The origin of the localized zone of coarse grain lies in the formation during extrusion of fine grain, which frequently shows strongly preferred orientation, and subsequent grain growth on heat treatment. Practical effects of this coarse grain include inferior mechanical strength in the regions of large grain, variations in mechanical properties across the extruded section and reduction in shear strength at the interface between coarse and fine-grained zones.

Considering the problem in broad terms, it is clear that heterogeneity of the type mentioned can be combatted in at least three ways: (*a*) by modifying the conditions of extrusion, (*b*) by introducing additional hot work and its associated recrystallization, (*c*) by altering recrystallization characteristics by modifying the heat treatment cycle or chemical composition.

It has been found in practice that of all the possible factors that can be varied under the heading "extrusion conditions", the design of die in relation to the container is the most significant. Other possibilities, such as to use indirect extrusion or to accept a high scrap loss on each extruded length, find little favor for economic reasons.

Technically, the application of a further hot working process after extrusion would counter the grain size problem, but it is clearly possible only with sections having very simple geometry.

The most significant possibilities emerge from the third group, which concerns recrystallization characteristics. A considerable amount of data

(*Continued on p. 190*)

*Digest of "The Influence of Additions of Zirconium on the Crystal Structure of Extruded and Heat Treated Aluminum Alloy Semifinished Products", by J. Herenguel and M. Scheidecker, *Revue de Metallurgie*, Vol. 51, March 1954, p. 173-178.

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Carburizing trays of cast Nichrome used by Nash Motors for carburizing pinions, bevel gears, and miscellaneous small gears. The trays are used in a Surface Combustion pusher-type furnace, with 4 zones of temperature control: at 1550°F., 1700°F., 1700°F., and 1525°F.

Each tray is in the furnace approximately 8 hours, carries a gross load of about 80 lbs. The carburizing temperature is a mixture of RX gas and propane. After discharge from the furnace, the trays, together with the pinions and small gears, are quenched in an oil bath.

8 HOURS in the carburizing furnace, with 3 temperature changes. Then rapid cooling, followed by quenching in an oil bath. Then back into the furnace. That's the kind of service Nash Motors demands of their carburizing equipment.

And that's why they chose Nichrome for the trays shown here. For Nichrome *stands* this kind of service . . . gives a far lower heat-hour cost than any other equipment they have used.

"Estimated life of these trays is two years" says Mr. C. A. Jorgensen, Assistant Plant Engineer at Nash Motors. "Trays purchased before order M-80 went into effect [AUGUST, 1951] are still in serviceable condition, and we do not expect to replace them for some time to come."

*T.M. Reg. U.S. Pat. Off.

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Grain Growth . . .

has been accumulated on the effects on grain size and mechanical properties of variations in solution heat treatment and it is established that the range of times and temperatures within which satisfactory solution heat treatment can be effected is very restricted. The limiting factors are those governing adequate solution of second phase, grain growth and minimum time for attainment of temperature uniformity. Factors of additional, but secondary, importance are overheating temperature and maximum time of treatment economically feasible.

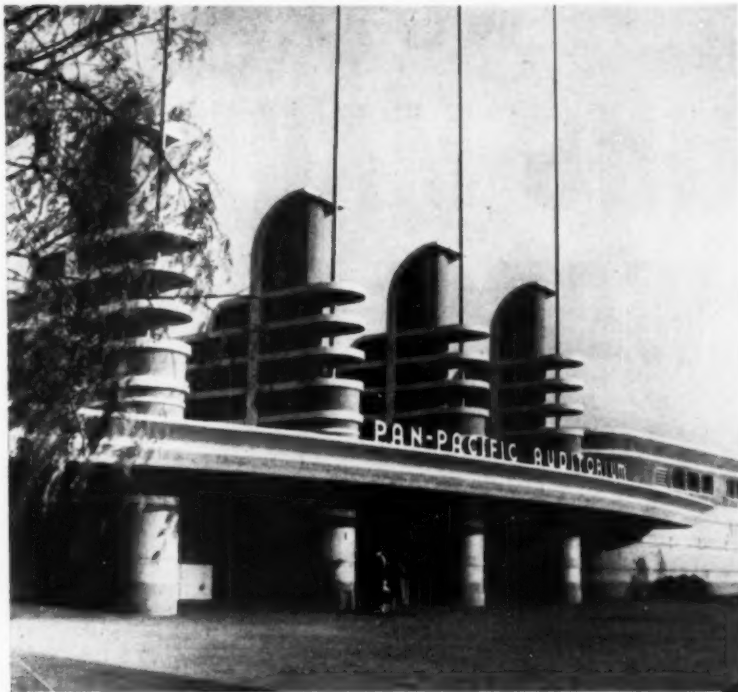
Advantage can be taken, however, of changes which can be brought about in recrystallization characteristics by modification of composition. Manganese has been well established for its effect in retarding recrystallization and extending the time-temperature range, without excessive grain growth. For example, solution treatment at 895° F. must be confined to about 6 min. to avoid excessive grain growth in a low-manganese alloy. Addition of 0.6 to 0.8% manganese extends the "safe" period at that temperature to at least 1 hr.

Zirconium has been found to act similarly and even more potently and to exert its effect in a wide range of aluminum alloys. The relative effects of manganese and zirconium show up in alloy A-ZG containing 2% silicon and 3.25% magnesium in which recrystallization begins at about 750° F. in the absence of special additions, near 930° F. when 0.8% manganese is added, and above 975° F. when 0.2% zirconium is added. The influence of zirconium is progressive but in practice the zirconium content should not exceed 0.2% and best results are had with both zirconium and manganese.

Zirconium can be added by use of a master alloy containing 5% zirconium in aluminum, or by way of a slag (for example, a slag containing fluozirconate); either method is found to give consistent results.

While the merits of zirconium in retarding recrystallization and grain growth and so countering the grain size effect are potentially very important in the extrusion of aluminum alloys, it must, however, be accepted that the high cost of zirconium is a limiting factor. C. B. LANDER

'55 WESTERN METAL EXPOSITION



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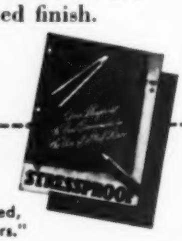

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Research in the United States*

THE PURPOSE of this paper is to define the different American research organizations, grouping them according to their origin – governmental, educational, industrial, cooperative or private – and to compare them with European research organizations. The ideas and opinions expressed are the result of a two-month trip to the U. S. and are based largely on direct observation.

In his attempt to reveal certain aspects of the influence of research on the success of American industry (which was the aim of the O.E.E.C. mission of which he was a member), the author devotes considerable attention to the close relationship of technical research with the aforementioned organizations. He observes that the commercial point of view predominates in research sponsored by industry and to this end the primary interest is directed to realizing economy of time and economy of materials. As a consequence, the product that is evolved is not the best possible product but one that is satisfactory and of low cost.

That the utilitarian value of this country's industrial research seems to have made a profound impression on the author – at least it will strike one who has lived with this attitude that he is so impressed – is evident throughout the report. He does not overlook the economist, the business man and financier and their roles in research – this research beginning with a study of the market and the careful selection of a research project, both of these being selected on their economic worth. The goals of industrial research as outlined in a company publication are cited as being typical of the American attitude:

1. To solve, or better anticipate, difficulties relative to raw materials, manufacturing methods, manufactured products; to improve production techniques.
2. Reduce expense at each stage.
3. Improve the quality of raw materials and products.

(Continued on p. 196)

*Digest of "Research—One of the Factors in the Industrial Success of the United States", by Georges Delbart, *Fonderie*, January 1954, p. 3745-3754 (translated by Dorothy F. Thum).

Twelve Papers on Furnace Atmospheres To Be Given At Metal Show On IFMA Day!

Protective atmospheres are saving money, improving quality, and speeding production in the metalworking industry. But, based on numerous inquiries received by the Industrial Furnace Manufacturer's Association (IFMA), it became apparent that there was a definite need for a logical, orderly collation of the latest thought on the process.

Months of planning by a special IFMA committee will be culminated on Tuesday, November 2nd, IFMA Day, at the Metal Show in Chicago when twelve national authorities will present the latest theory and practice on the generation, control and application of furnace atmospheres.

The panel type sessions will start in the morning at the Palmer House with a paper by A. Hotchkiss on the theory of atmosphere gases. Following papers by W. Boyd, D. Beggs, M. Ogle, N. Koebel and R. J. Perrine will discuss in detail the construction and operating techniques of atmosphere generators. The morning session will close with a report by W. Besselman on control and safety in the use of atmospheres.

In the afternoon, the sessions will shift to the Exhibition Hall, the site of the Metal Show. Papers on the applications of furnace atmospheres will be given by W. Holcroft, D. Cullen, H. Ipsen, A. Frank and C. Paulson.

A new movie on the brazing process will be shown.

Extensive correspondence between participating speakers has eliminated any possibility of repetition of material. A 12 minute time limit for each subject assures that only the important theories, facts and problems will be discussed.

Future issues of METAL PROGRESS will report each paper in detail. At a later date, it is expected that the papers will be incorporated into an authoritative text.

IFMA is also participating in a similar panel type session on high frequency induction heating to be held in conjunction with the Metal Show. Details will be announced shortly.

Cary H. Stevenson will act as moderator at panel session.

Les H. Gillette, President, Industrial Furnace Manufacturers Association

U. S. Research . . .

4. Reduce expense of upkeep and of consumer use.
5. Investigate the application of materials and new processes.
6. Develop satisfactory substitutes.
7. Recuperate and utilize by-products and waste.
8. Accumulate technical knowledge and information.
9. Develop markets.

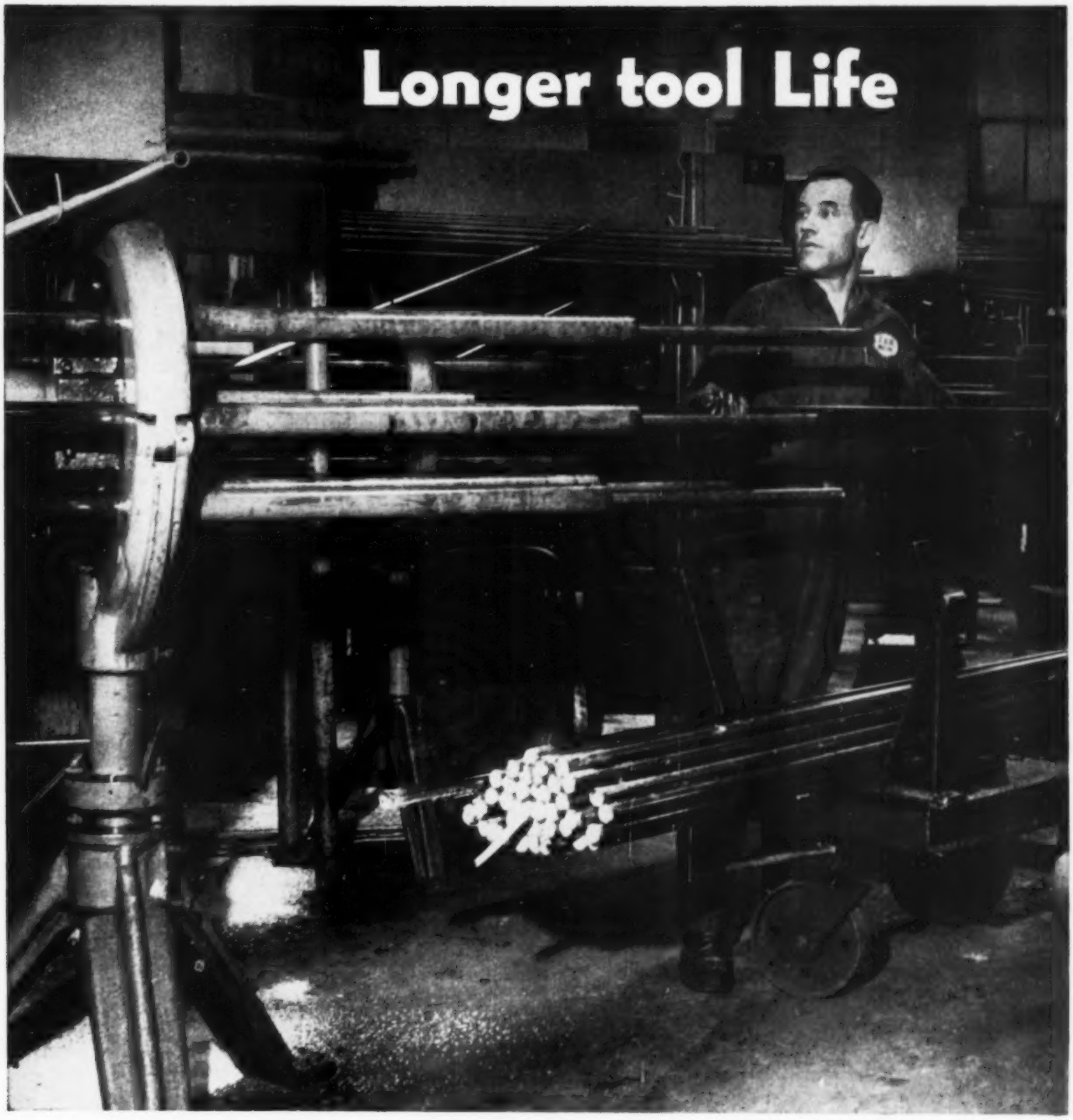
A very important consideration, even a predominant one, is given to engineering: the effort that pertains to the transition of laboratory discoveries to factory products, a process that is generally identified in this country by the word "development". The European researcher, concerned with his pride of dignity and his disinterestedness, has for a long time underestimated the importance of development. For the American, development is an essential part of industrial research; in fact, the American administrator of industrial research considers that for each laboratory researcher approximately ten engineers and technicians are necessary for development. Which gives an idea of the importance of this concept.

General control of research in the big industrial companies is in charge of one of the vice-presidents; such an administrator is not common in Europe. Also uncommon in Europe are the special courses in management and organization that are offered in American universities. The author remarks that research administrators are generally mature men and often graybeards, but research directors and researchers are very often young, the experience of older men thus being combined with the enthusiasm and creative faculties of young researchers.

In undertaking to compare American and European technical research, the advantages and limitations of each with regard to factors of a geographic, political, economic, fiscal, technical and psychological nature should be kept in mind, for they differ considerably.

The European researcher is often of the university tradition, independent and haughtily disinterested—even to an attitude of romanticism. There are many exceptions and these

(Continued on p. 198)



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U. S. Research . . .

exceptions may soon become the rule, but there is no question that the American is more utilitarian. The European researcher of university tradition is often willing to limit his efforts to bibliography and laboratory research, whereas the American concentrates on the paying project and on development – often using the laboratory research of the European, who either supplies the ideas and the basic data or becomes an expatriate.

Basic research is certainly still honored in the U.S., but the fact is that industrial research is everywhere, even in the universities. This is in sharp contrast with the European universities which traditionally work in a disinterested way.

Although fundamental research has not been neglected in the U.S. (one has only to follow the scientific publications for proof), there has been deviation, and utilitarian research has made serious invasion upon the time and effort that should be devoted to it. The U.S. government, itself largely responsible for this state of affairs, is now trying to rectify the condition.

The author concludes with strong emphasis on the important interpenetration which exists in the U.S. between research laboratories and various administrations. Organizations having diverse interests keep in touch with each other and with current events, and make a point of finding the center with the *ad hoc* equipment and the specialized scholar, and of using them on their own ground. These connections and interpenetrations put research men in contact with real life to the great profit of the community.

The author summarizes his opinion on the American approach to research with the admonition: "We must remember that in the ceaseless world struggle our research must be efficient; that is, it must be rapidly developed. That is why I will end this paper with the word so honored in the U.S. – development".

J. P. Jr.

Steel Cartridge Cases*

Caliber .45 steel cartridge cases were made in great numbers by Chrysler Corp. at Evansville, Ind., but this plant was dismantled at the end of World War II. In 1952 some of the stored machinery was put into a new operation at Twin Cities Arsenal by Federal Cartridge Corp. using substantially the old practice, and Mr. King says that either brass or steel cartridges can be made.

First operation is blanking disks and forming cups in a double-action press making five cups per stroke. Short punch and die life was cured by filtering the recirculating lubricant cleanly of metal fragments and using a lubricant with some bite, which would wet and stick to the smooth strip. After alkaline wash, 100% visual inspection rejects any scratched or otherwise defective cups. Annealed strip of high and uniform quality is necessary, free of laminations or inclusions.

Cups are then annealed in protective atmosphere – an operation of prime importance – in Lindberg or Sunbeam furnaces. Cups are loaded on a conveyer belt and stay 30 min. in the furnace, whose first zone is at 1320 and the second at 1400° F. A long cooling chamber delivers bright work to Stephens phosphating units (traveling barrels). Cases are alkaline cleaned, phosphated, and soap coated after each draw. Phosphate and soap have these advantages over Chrysler's use of a copper dip-plate: better corrosion protection; better tool life; easier removal at the end. Dies have carbide inserts; punches are of polished steel; coolant is dilute soap solution. Production of 400 per min. per press equals usual speed for brass cartridges.

After the second draw the cases are normalized 30 min. in a continuous furnace, 1600° F. in the first zone, 1725 in the second. The third draw gives the wall the correct thickness and diameter. Cases are trimmed to length, primer pocket formed, and extracter groove cut.

A certain proportion of caliber .45 cartridges have split when fired in the M3 submachine gun, due to lack of support (large clearances in the

(Continued on p. 200)

*Digest of "Steel Cartridge Cases", by William N. King, *Ordnance*, July-August 1954, p. 49.

gun chamber). Specifications now allow only one-third the number of splits. This requires a stress-relief, 6 min. at 1250° F.

After inspection for size, the cartridge cases are zinc plated, chromated for rust resistance, and are ready for loading and priming.

Decision to make steel cartridge cases at Twin Cities Arsenal was reached late in 1952. Production started in May 1953. Scheduled production has been met or exceeded monthly since September 1953.

E. E. T.

Replacement of Mo by V for High-Tensile Steels*

THIS ARTICLE is a continuation of work by the British Welding Research Assoc. on a series of 35 experimental low-carbon weldable steels of high tensile strength last reported in *Welding Research*, Vol. 7, August 1953. Two compositions known as A and B appeared most promising, composition of these being as follows: (A) – 0.13 to 0.17 C, 0.80 to 1.00 Mn, 0.30 (max.) Si, 0.50 to 0.70 Ni, 0.80 to 1.00 Cr, and 0.20 to 0.24% Mn; (B) – 0.13 to 0.17 C, 1.00 to 1.20 Mn, 0.30 (max.) Si, 0.20 (max.) Ni, 0.50 to 0.70 Cr, and 0.20 to 0.24% Mo.

The most recent work, summarized herewith, concerned 12 additional experimental steels based on the composition of steels A and B with vanadium replacing part or all of the molybdenum. To simulate the cooling conditions of 1½-in. thick plates, a "sandwich" technique was used whereby ½-in. square bars were clamped between ½-in. plates for tensile tests, and ½-in. thick plate was clamped between ½-in. plates for Izod impact tests. The sandwiches were normalized by heating at 1650° F. for 1½ hr. and were then cooled in still air.

As shown by the following table, the significant effect of replacing about 0.23% Mo with about 0.13% V is to double the 0.02% proof stress with a substantial increase in ductility as measured by the reduction of area.

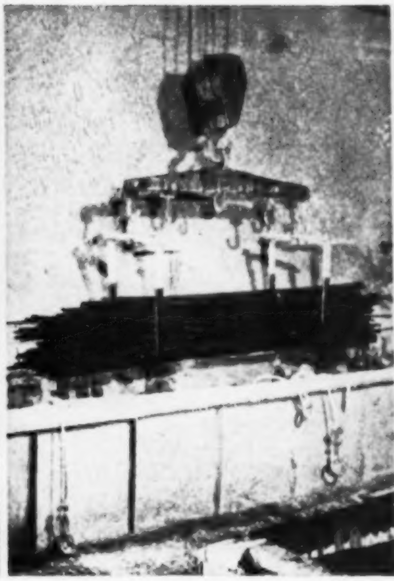
Izod (3-notch 10-mm. square) tests were run on steels of the A series and, as shown on p. 202, the vanadium steel (56) has better notch-toughness and a lower transi-

(*Continued on p. 202*)

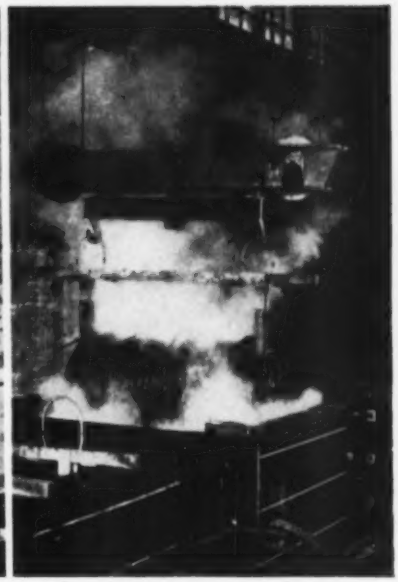
	STEEL A	No. 56	STEEL B	No. 63
Carbon	0.14%	0.15	0.14	0.13
Manganese	0.89	0.78	1.14	1.13
Silicon	0.18	0.09	0.30	0.14
Nickel	0.56	0.73	0.23	0.12
Chromium	0.93	0.92	0.66	0.69
Molybdenum	0.22	–	0.24	–
Vanadium	–	0.14	–	0.12
0.02% Proof stress, psi.	29,100	59,100	26,200	55,200
Tensile stress, psi.	84,300	84,300	89,600	76,900
Reduction of area, %	63	72	59	75

*Digest of "Vanadium as a Replacement for Molybdenum in Low-Alloy Steels", by C. L. M. Cottrell and B. J. Bradstreet, *British Welding Journal*, Vol. 1, February 1954, p. 82-86.

TOOL STEEL SHEETS



STAINLESS STEEL BAR STOCK



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High-Tensile Steels . . .

tion temperature than the molybdenum type:

Test Temperature	Izod, Ft.-Lb. Steel A	No. 56
68° F.	20	70
32	15	75
–4	8	60
–40	6	38

Minimum temperature for 50% sheer fracture was 86° F. for Steel A and –22° F. for Steel 56.

While no data were presented, the authors have rated the weldability of the vanadium steel as the equal of the standard molybdenum type (A and B).

In the series of steels investigated were some with about 0.22% V.; these showed little improvement in yield stress and a somewhat higher transition temperature than those with 0.14% V, so that there is no need to go beyond this level. Also, steels with lower Mo (about 0.15 to 0.19%) plus about 0.14% V had less desirable Izod values and weldability than the steels with vanadium but no molybdenum.

The improved yield and notch-toughness properties of the vanadium steels is attributed to their fine-grained ferritic-pearlitic structure, whereas the molybdenum steel contained a small amount of the lower bainite structure. The authors believe that tempering the molybdenum steels improves yield strength and lowers transition temperature.

The findings of this investigation are in good agreement with the relative effect of molybdenum and vanadium on the normalized properties of low-alloy steels in this country. It is doubtful that the properties reported for normalized 1½-in. thick plate could be consistently maintained in as-rolled plates because of the effect of variations in finishing temperature on the solubility of vanadium carbide as well as on the grain size. Still, the preferred composition would require normalizing

American developments, utilizing vanadium in low-alloy steels for high yield strength, high notch-toughness and good weldability, have been directed toward still lower levels of vanadium (less than 0.10%) with results, in general, quite similar to those reported here.

P. R. Wray

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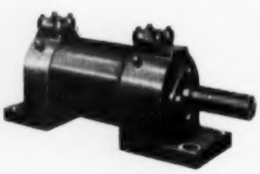
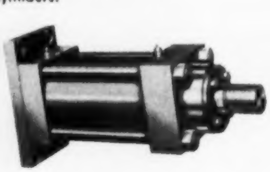


ACIPCO STEEL centrifugally spun tubes were employed in the construction of the 3000 psi (above) and 2000 psi (below) hydraulic cylinders.



NEEDLESS TO SAY, the hydraulic press shown above and others like it must be built to withstand a lot of rugged punishment. Many of these industrial giants employ various types of hydraulic cylinders constructed of ACIPCO STEEL centrifugally spun tubes for shuttle feed use and the like.

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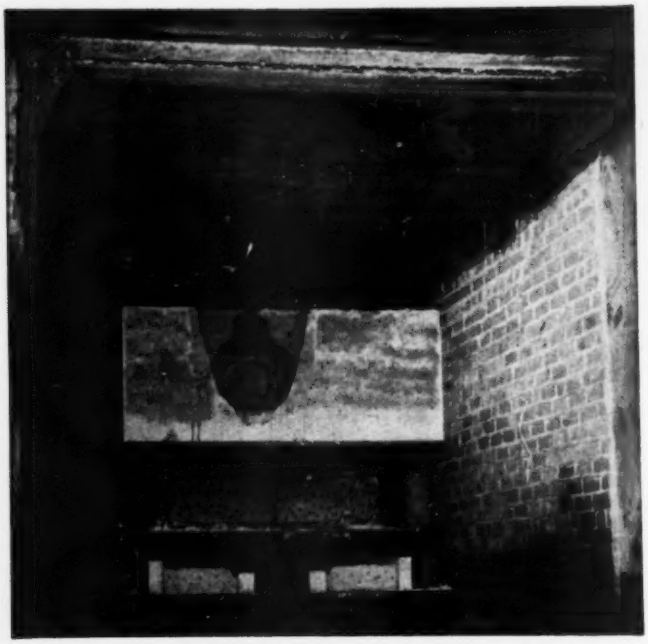

Pre-cast roof sections of refractory concrete shown in place on completed core oven at Penn Steel Castings Company, Chester, Pa.

Pennsylvania Plant Takes Advantage of New Pre-Casting Technique

Flat-arch core oven roofs can be pre-cast quickly and easily with a new technique like the one used at Penn Steel Castings Company, Chester, Pa. (see photos). In this case, plant personnel cast monolithic roof sections on the job, then lowered these panels into place to complete the flat arch.

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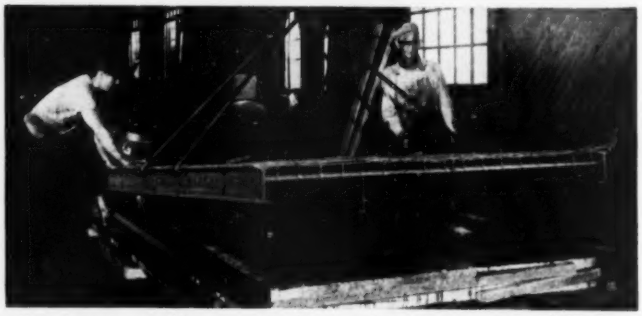
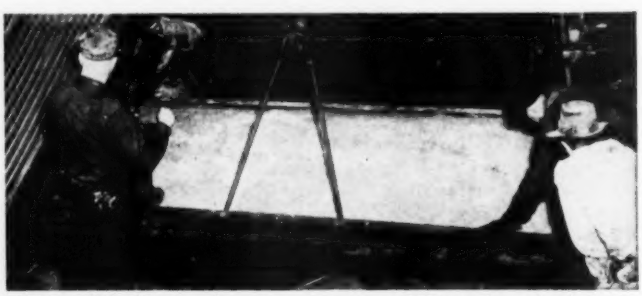


Plant personnel have put finishing touches on one cast panel. Moving into position is an I-beam frame with reinforcing for another panel.



Being fitted into place, a pre-cast monolithic section of refractory concrete shows this method's convenience of handling.

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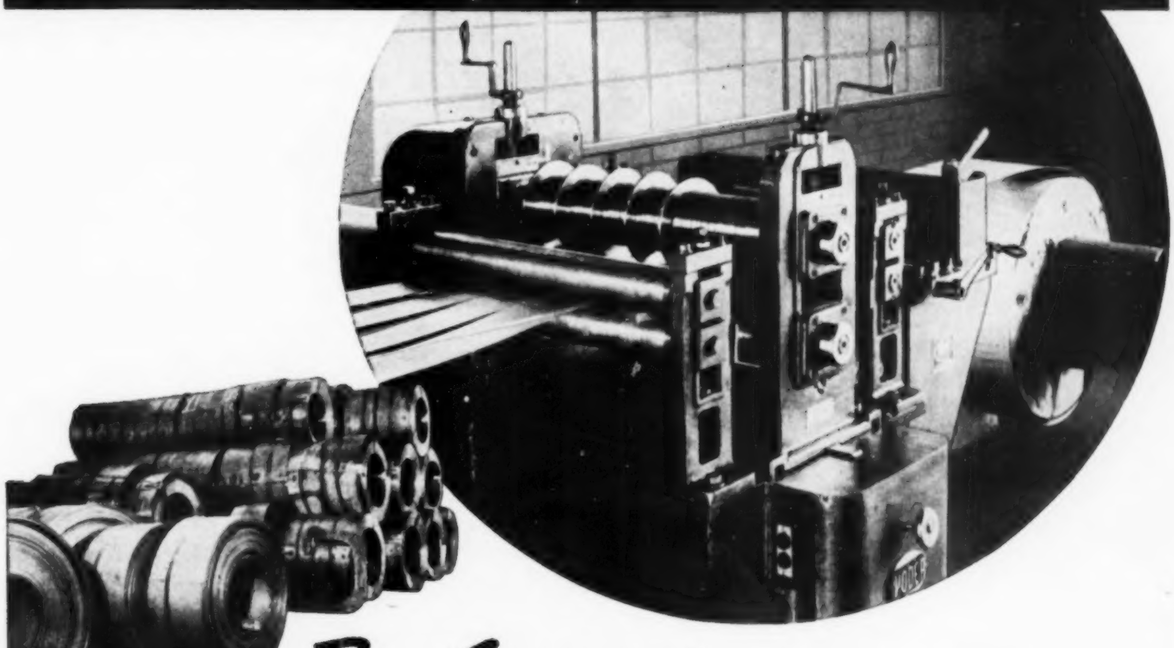

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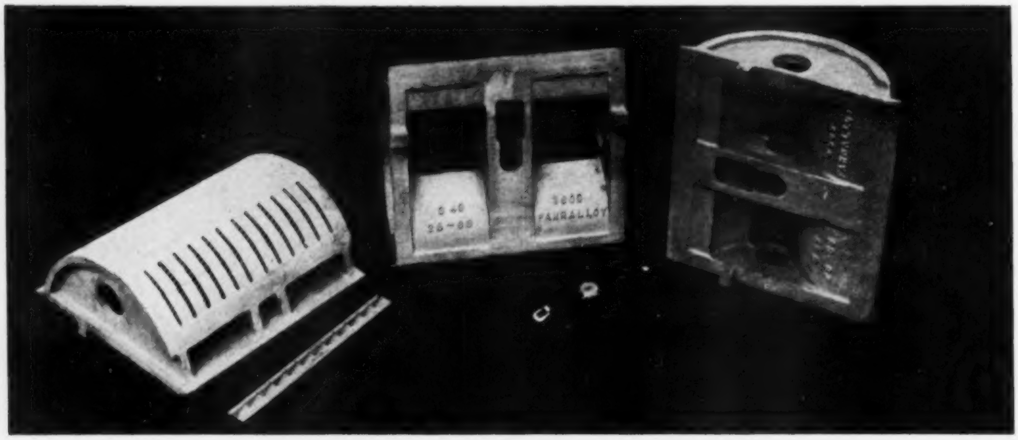

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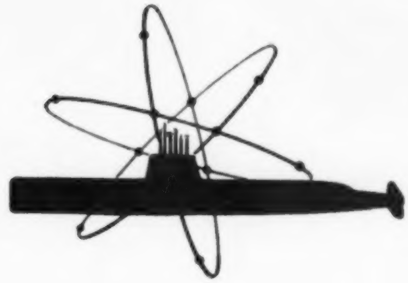

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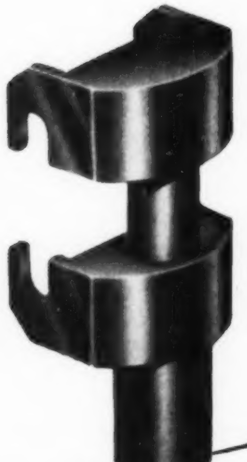

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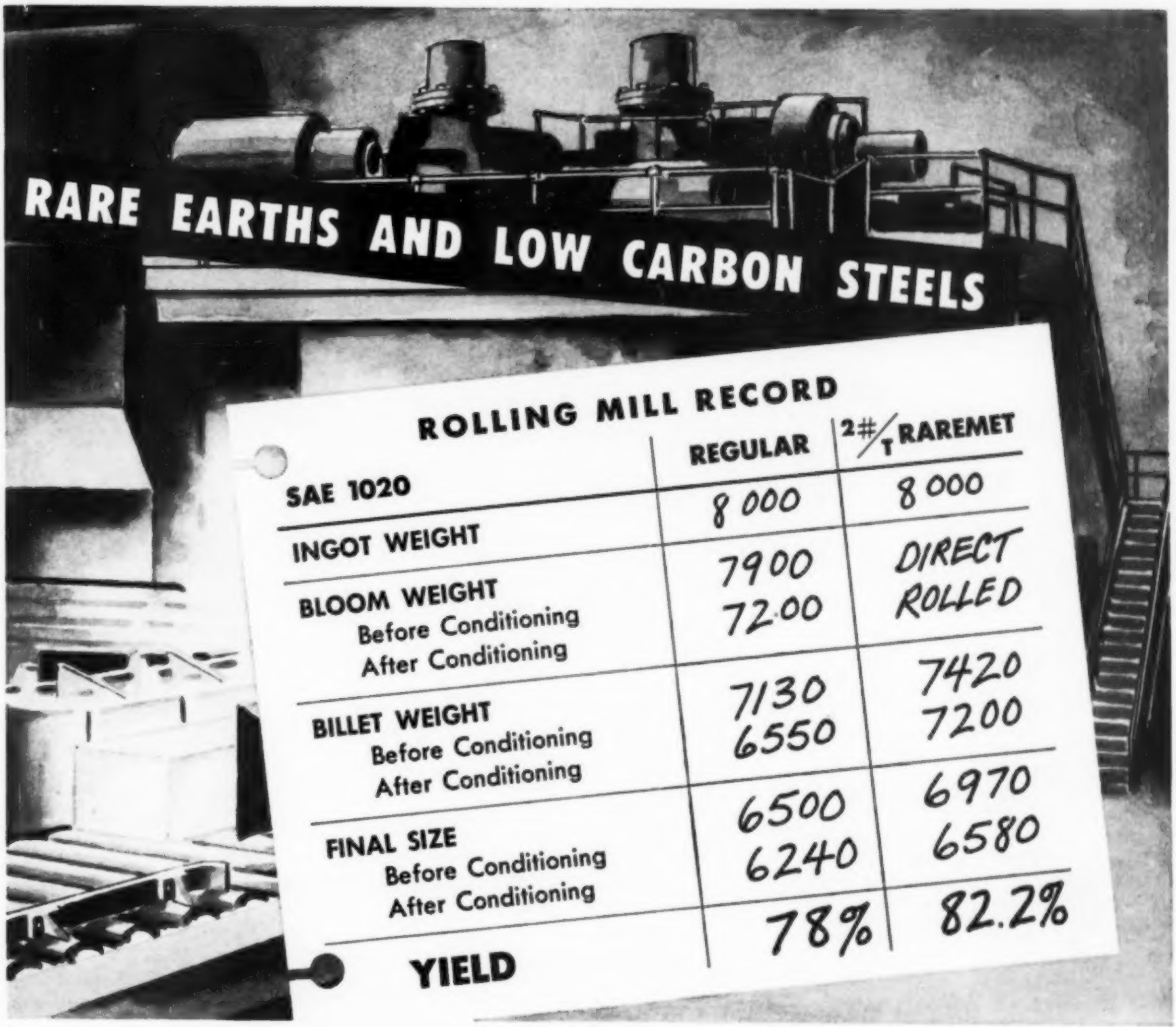

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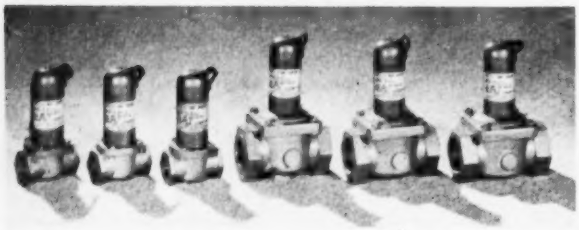

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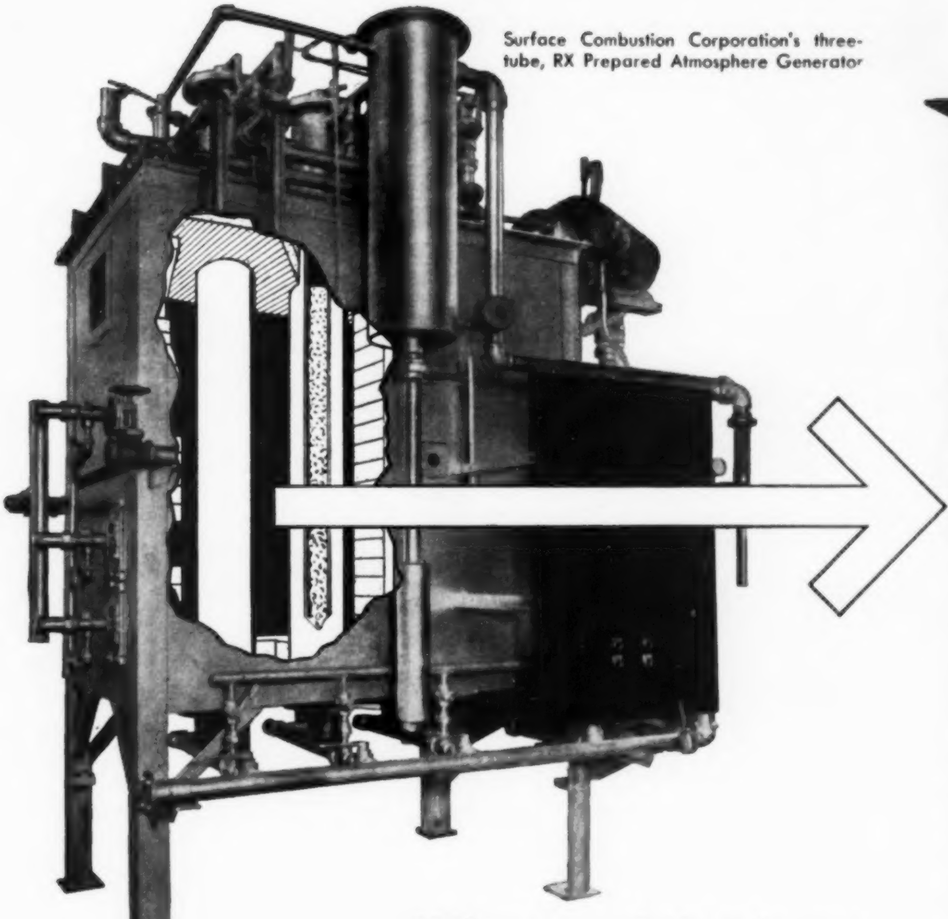

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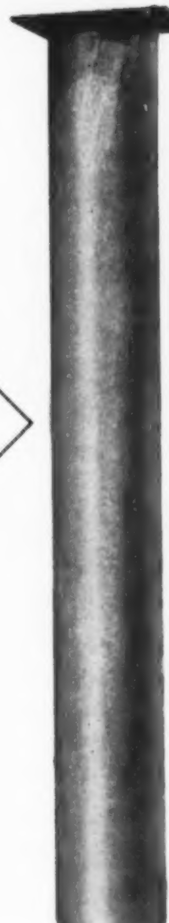

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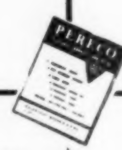

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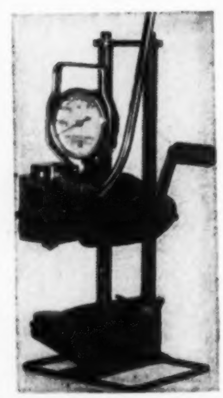

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Invitation to Entrants

9th Metallographic Exhibit

Entries are invited in the 9th Metallographic Exhibit, to be held at the National Metal Exposition in Chicago the week of Nov. 1 through 5, 1954. Entries will be displayed to good advantage and awards will be given for the best micrographs as decided by a committee of judges.

Classifications of Micros

1. Toolsteels and tool materials
2. Stainless steels and heat resisting alloys
3. Other steels and irons, cast or wrought
4. Aluminum, magnesium, beryllium, titanium and their alloys
5. Copper, nickel, zinc, lead and their alloys
6. Metals and alloys not otherwise classified
7. Series showing transitions or changes during processing
8. Welds and other joining methods
9. Surface phenomena
10. Results by unconventional techniques (other than electron micrographs)
11. Slags, inclusions, refractories, cermets

Awards and Other Information

A committee of judges will be appointed by the Metal Congress management which will award a First Prize (a medal and blue ribbon) to the best in each classification. Honorable Mentions will also be awarded (with appropriate medals) to other photographs which, in the opinion of the judges, closely approach the winner in excellence. A Grand Prize, in the form of an engrossed certificate and a money award of $100, will also be awarded the exhibitor whose work is adjudged best in the show, and his exhibit shall become the property of the American Society for Metals for preservation and display in the Society's National headquarters in Cleveland.

All photographs may be retained by the Society for one year and placed in a traveling exhibit to the various Chapters. They will be returned to the owners in May 1955 if so desired.

Rules for Entrants

Work which has appeared in previous metallographic exhibits held by the American Society for Metals is unacceptable. Photographic prints shall be mounted on stiff cardboard; maximum dimensions should be limited to 15 by 22 in. Heavy, solid frames are not permissible because of difficulties in mounting the exhibit. Entries should carry a label on the face of the mount giving:

Classification of entry
Material, etchant, magnification
Any special information as desired

The name, company affiliation and postal address of the exhibitor should be placed on the BACK of the mount.

Transparencies or other items to be viewed by transmitted light must be mounted on light-tight boxes wired for plugging into lighting circuit, and built so they can be fixed to the wall.

Entrants living outside the U.S.A. should send their micrographs by first-class letter mail endorsed "Photo for Exhibition—May be opened for customs inspection." To be acceptable as first-class mail the package should measure no more than 35 x 45 cm. (14 x 18 in.)

Exhibits must be delivered before Oct. 15, 1954, either by prepaid express, registered parcel post or first-class letter mail, addressed to:

National Metal Exposition
International Amphitheater
43rd and Halsted Sts.
Chicago 9, Ill.

36th National Metal Congress and Exposition

Chicago, Ill. **November 1 to 5, 1954**

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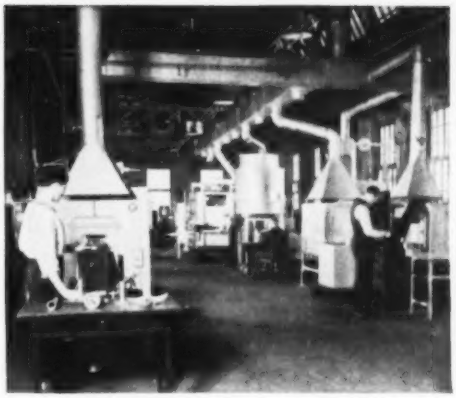
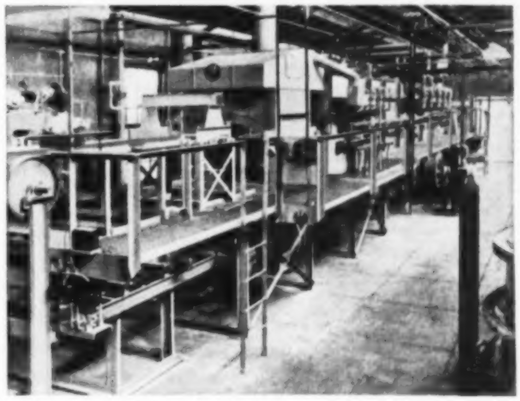


General view of the research department showing several of the continuous and batch type experimental furnaces.

● The EF research department is equipped with gas-fired, oil-fired and electrically heated continuous and batch units including, — continuous wire mesh furnaces;—endothermic and exothermic special atmosphere generators; — forced circulation bell furnaces; — a continuous roller hearth furnace for treating commercial widths of ferrous and non-ferrous strip; — and other equipment.



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